DOCUMENT RESUME

ED 371 158 CE 066 616

AUTHOR	Kaltwasser, Stan; Flowers, Gary
TITLE	Commercial and Industrial Wiring. Second Edition.
INSTITUTION	Mid-America Vocational Curriculum Consortium, Stillwater, Okla.
PUB DATE	94
NOTE	714p.; For related curriculum guides, see CE 066 615-617.
AVAILABLE FROM	Mid-America Vocational Curriculum Consortium, 1500 West Seventh Avenue, Stillwater, OK 74074-4364 (order no. CN801401).
PUB TYPE	Guides - Classroom Use - Teaching Guides (For Teacher) (052)
EDRS PRICE	MF04 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Basic Skills; Behavioral Objectives; Blueprints; *Competency Based Education; *Electrical Occupations; *Electric Circuits; *Electricity; *Electronic Control; Equipment Utilization; Evaluation Criteria; Job Skills; Learning Activities; Mathematics Skills; Safety; Secondary Education; Student Evaluation; *Trade and Industrial Education
IDENTIFIERS	Electrical Wiring; *Industrial Wiring

ABSTRACT

This guide is designed to assist teachers conducting a course to prepare students for entry-level employment in the commercial and industrial wiring trade. Included in the guide are 15 instructional units and the following sections of information for teachers: guidelines in using the unit components; academic and workplace skills classifications and definitions; competency profile; instructional/task analysis; list of related academic and workplace skills; list of tools, equipment, and materials required to complete the assignment/job sheets; a 24-item reference list; and a glossary. The following topics are covered in the instructional units: blueprint reading and load calculations, tools and equipment, service, transformers, rough-in, lighting, motors and controllers, electrical diagrams and symbols, two- and three-wire controls, separate control circuits, sequence controls, jogging controls, reversing starters, special control circuits, and programmable controls. Each unit contains some or all of the following: objective sheet, suggested activities, assignment and written test answers, written test, unit evaluation form, teacher supplements, transparency masters, information sheet, student supplements, assignment sheets, and job sheets (lists of criteria for evaluating student performance). (MN)

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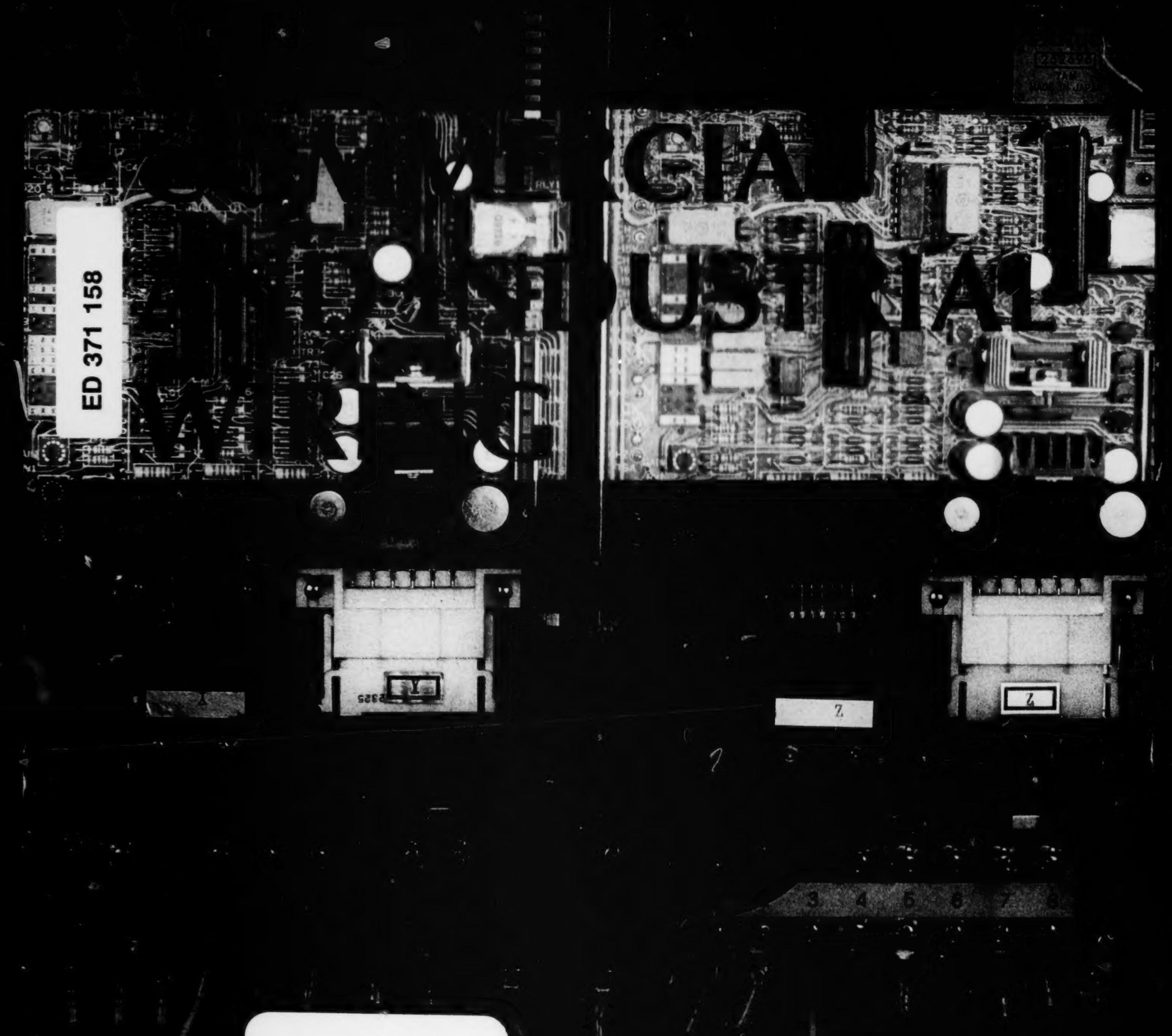
COMMERCIAL AND INDUSTRIAL WIRING



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Commercial and Industrial Wiring

Second Edition

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94-010140 CN801401

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Printed in the United States of America by the
Oklahoma Department of Vocational-Technical Education
Stillwater, OK 74074-4364

Mid-America Vocational Curriculum Consortium, Inc.
1500 West Seventh Avenue
Stillwater, OK 74074-4364

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Commercial and Industrial Wiring
Second Edition

Teacher Edition

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Foreword

Commercial and Industrial Wiring is the third in a series of three wiring publications and includes the additional technical knowledge and applications required for job entry in the commercial and industrial wiring trade.

Basic Wiring; the first publication in the series, serves as the foundation for students enrolled in a wiring program. It is a prerequisite to either *Commercial and Industrial Wiring* or *Residential Wiring*. An applied math unit has been added in the second edition of *Basic Wiring*, ©1993. This series should provide the flexibility that instructors need to meet the individual needs of their students and the community.

Residential Wiring, the second publication in the series, picks up where *Basic Wiring* ends and prepares the student for entry-level employment in the residential wiring trade. A new unit on SMART HOUSES has been added in the second edition of this publication.

MAVCC's wiring series was developed with the assistance of many individuals who have expertise in various areas of the wiring trade. Some of these individuals represent professional associations and industry. Their assistance and support is greatly appreciated. It should be emphasized that the student needs to be aware of professional trade associations and take an active part in them as much as possible. The professional trade associations, as well as vocational education, are an excellent avenue for continuing education within the electrical trade.

These instructional materials are designed not only for student use but also to assist the teacher in improving instruction. Every effort has been made to make these materials basic, readable, and usable. Teachers will need to develop instructional strategies for localizing, individualizing, and supplementing these materials.

Special attention should be given to the list of related academic and workplace skills in the introductory pages and to the teaching suggestions in each unit of instruction. These suggestions present academic skills being reinforced by the instructional materials and ways to increase reinforcement of workplace skills. By reinforcing basic skills, the teacher will assist students in becoming more productive workers.

As you use these instructional materials, we hope you will find they contribute to the quality of your program. If any problems occur or if you have suggestions for improvement, please call or write us.

Mervin Birdwell, Chairman
Board of Directors
Mid-America Vocational
Curriculum Consortium

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Executive Director
Mid-America Vocational
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Acknowledgements

Appreciation is extended to those individuals who contributed their time and talent to the development of *Commercial and Industrial Wiring.*

The contents of this publication were initially planned and reviewed by the following committee members:

Loren Amerine	Hoisington, Kansas
Bill Barnes	Littleton, Colorado
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Review of this publication was completed by selected representatives of the Carolinas Construction Training Council. Special appreciation is extended to Tommy Caldwell, chief executive officer of the CCTC for planning and coordinating the technical review meeting.

A special thank you goes to the following for granting MAVCC permission to reprint certain graphic materials that enhance this text: Jim Johnson, Telemecanique, Inc.; Mike Wanless and Dan Rood, Hunzicker Brothers; Tel-A-Train Inc.; Advance Transformer Company; Square D Company; and Cutler-Hammer.

Appreciation is also extended to Stan Kaltwasser, technical consultant; Donna Bellmon, technical artist; and to members of the Oklahoma State Vo-Tech Print Shop for their excellent service in printing the text.

The text was phototypeset in the Oklahoma Department of Vocational and Technical Education Communications Center, and for their excellent contribution, a thank you goes to phototypesetters Alisa Hines and Karen Hart.

Thanks are also extended to Sue C. Feasley, editor of this project, and to Jane Huston, MAVCC curriculum coordinator.

Use of Introductory Materials

Introductory materials are included in the teacher guide only and contain useful information to assist administrators and teachers in planning for instruction.

In addition to the general information such as the table of contents, foreword, and acknowledgements page, information is included on the following:

1. **Use of this publication**—Explains the components of a unit of instruction and how they should be used as part of the teaching/ learning process.
2. **Competency profile**—Provides a record of student performance for each task included in a unit of instruction. This becomes a part of the student's permanent records and should be utilized when directing the student toward employment opportunities.
3. **Instructional/task analysis**—Provides a quick review of contents of the publication; identifies cognitive (knowledge) skills and psychomotor (doing) skills addressed in each unit of instruction.
4. **Related academic and workplace skills list**—Classifies unit tasks (assignment sheets and job sheets) according to related academic and workplace skills being reinforced. Skill areas reflected by skill groups, sub skills, and descriptions have been identified using *Workplace Basics: The Skills Employers Want*, developed by the American Society for Training and Development (ASTD) and the U.S. Department of Labor and adapted by MAVCC.
5. **Tools, equipment, and materials list**—Provides a comprehensive list of those items needed to successfully complete the assignment sheets and/or job sheets; assists administrator/teacher in determining program costs.
6. **Reference list**—Provides a comprehensive list of resources used in the development of this publication.
7. **Glossary of terms**—Provides a comprehensive list of terms and definitions found in Objective 1 of all units of instruction.

As you use these materials, it is hoped that they will provide useful information to meet a variety of needs.

Use of This Publication

Instructional units

Commercial and Industrial Wiring contains fifteen units of instruction. Each instructional unit in a teacher guide includes some or all of the following basic components of a unit of instruction: objective sheet, suggested activities for the teacher, answers to assignment sheets, answers to written test, written test, unit evaluation form, teacher supplements, transparency masters, information sheet, assignment sheets, student supplements, and job sheets.

All of the unit components focus on measurable and observable learning outcomes. Teachers are encouraged to supplement, personalize, localize, and motivate with these materials in order to develop a complete teaching/learning process.

Units of instruction are designed for use in more than one lesson or class period of instruction. Careful study of each unit of instruction by the teacher will help to determine the following:

- Amount of materials that can be covered in each class period.
- Skills that must be demonstrated.
- Amount of class time needed for demonstrations.
- Amount of time needed for student practice.
- Supplementary materials, including print and nonprint media and equipment and supplies, that must be ordered.
- Resource people who must be contacted.

Objective sheet (Color code: White)

Each unit of instruction is based on performance objectives which state the goals for successful completion of the course. These performance objectives are stated in two forms: unit objectives which state the expected performance of each student after completion of the unit of instruction, and specific objectives which state what the student must do to reach the unit objective.

The objectives should be provided for students and stressed throughout the teaching/learning process. This will help answer any questions concerning performance requirements for each instructional unit. The objectives can also help determine teaching strategies and instructional methods. Teachers should prepare for each unit by deciding how each objective can best be taught.

Teachers should feel free to modify, delete, or add objectives in order to meet the needs of the students and community. When objectives are added, the teacher should remember to supply the needed information, assignment and/or job sheets, and criterion test items.

Use of this Publication

Suggested activities (Color code: Pink)

This component is included only in the teacher edition. The suggested activities assist teachers during the preparation stage of the teaching/learning process by providing an instructional plan, teaching suggestions, and a list of supplemental resources. Ways to integrate academic and workplace skills have been included in the teacher suggestions, and skill areas have been noted in bold. (A table of academic and workplace skills with accompanying definitions has been provided on page xv.) The teacher should read the suggested activities before teaching the units and decide how each objective can best be taught. Time should also be allowed to obtain supplemental materials, prepare audiovisual materials, and contact outside resources. Duties of the teacher will vary according to the particular unit.

References used in the development of each unit are listed in the suggested-activities section, along with suggested supplemental resources that may be used to teach the unit. These materials can be used by the teacher to supplement her or his knowledge of the subject area or to help students with particular interests or objectives in the area covered.

Instructions for evaluating student performance on the job sheets are also included in the suggested-activities section. Teachers should select and discuss with students the rating scale that will be used.

Assignment and written test answers (Color code: Pink)

Assignment-sheet answers and written-test answers are designed to assist the teacher in evaluation of student performances.

Written test (Color code: Yellow)

This component provides criterion-referenced evaluation of every cognitive objective listed in the unit of instruction. The test appears in the teacher edition only, but duplication is permitted for student use. If objectives have been added, deleted, or modified, appropriate changes should be made on the written test. It is recommended that the tests be divided into shorter tests covering three or four objectives at a time and given soon after those objectives have been covered. A selection of test items from the units covered may be used for final tests at the end of each term if desired.

Unit evaluation form (Color code: White)

This sheet provides teachers with a record of each students performance on a unit of instruction. It includes space for assignment sheet ratings, job sheet ratings, written test scores, and teacher comments. The unit evaluation form is included in the teacher edition only, but may be duplicated.

Use of This Publication

Teacher supplements (Color code: White)

This component is included only in the teacher edition. Teacher supplements are optional materials for the teacher to use. They have three purposes: to provide the teacher with higher level materials to stretch the advanced student, with remedial information or practice to assist the less-advanced student, and with state-of-the-art information in which the teacher may not have background or with information that is not readily available in other books. Some teacher supplements may be duplicated for student use and are marked accordingly.

Transparency masters (Color code: White)

Transparencies are included in the teacher edition only and are used to direct the students' attention to the topic of discussion. They may provide illustrations, charts, schematics, or additional information needed to clarify and reinforce objectives included in the unit of instruction.

Information sheet (Color code: Green)

The information sheet provides the content essential for meeting the cognitive (knowledge) objectives of the unit. Teachers will find that the information sheet serves as an excellent guide for presenting background knowledge necessary to develop the skills specified in the unit objective. Students should read the information sheet before the information is discussed in class. Space is provided in margins for students and teachers to add notes that supplement, localize, personalize, or provide information for the teaching of each objective.

Student supplements (Color code: White)

Student supplements are included in the student edition. The information presented in a student supplement may consist of tables, charts, written information, forms, or other information students will need in order to complete one or more of the assignment and/or job sheets. Students are not directly tested over the information presented in a supplement; however, their ability to apply this information may be evaluated in the completion of assignment sheets or job sheets.

Assignment sheets (Color code: Tan)

Assignment sheets provide students with pencil and paper activities that give students the opportunity to make practical application of the knowledge in the information sheet. Criteria are provided to objectively evaluate student performance.

Use of this Publication

Job sheets (Color code: Blue)

The job sheets provide criteria to objectively evaluate student performance, a list of required equipment and materials, and a step-by-step procedure for performing a psychomotor skill. The teacher should discuss the equipment and materials available in the classroom and/or laboratory and demonstrate the procedure prior to having students practice procedure. When a student is ready to be evaluated, the teacher should follow instructions for evaluating student performance which may be found in the teacher edition.

Job sheets are an important segment of each unit. Job sheets provide potential employers with a picture of the skills being taught during training and the performances that might reasonably be expected from an individual who has had this training.

Disseminating material

Material may be given out a unit or page at a time to keep the material before the student always new. Some teachers ask students to furnish a three-ring binder or folder for the current unit of study. This is convenient for students taking the material home to study. Upon completion, each unit is then placed in a larger binder. Some teachers prefer to store the material by unit in filing cabinets or boxes until needed.

For best results, provide student materials for each student. Student editions contain objective sheets, information sheets, student supplements, assignment sheets, and job sheets. Students should be allowed to take their materials home at the end of the course.

Academic and Workplace Skills
(Classifications and Definitions)

Skill Groups	Sub Skills	Definitions
Learning Skills	Learning to learn	Developing ability to apply knowledge to other situations; knowing how to learn.
Foundation Skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
	Writing	Communicating a thought, idea or fact in written form in a clear, concise manner.
	Math	Applying computation skills such as reasoning, estimation, and problem solving as they are actually used on the job.
	Science	Applying knowledge learned through study or practice that is based on scientific principles as they relate to specific tasks.
Communication Skills	Listening	Listening for content, conversation, long-term contexts, emotional meaning, and directions.
	Oral communication	Communicating a thought, idea, or fact in spoken form in a clear, concise manner.
Adaptability Skills	Creative thinking	Using imagination to create something new—i.e. an idea, invention, work of art.
	Problem solving (critical thinking)	Recognizing and defining problems, inventing, and implementing solutions, and tracking and evaluating results.
Personal Management Skills	Self-esteem	Developing self-confidence and creating a positive self-image.
	Motivation/goal setting	Setting and meeting defined goals and objectives.
	Personal and career development	Emphasizing self-direction by establishing and implementing a plan.
Group Effectiveness Skills	Interpersonal relations	Developing ability to maintain positive relations with others.
	Negotiation	Resolving conflict between two or more individuals.
	Teamwork	Working together in a group to reach a common goal.
Influence Skills	Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Leadership	Directing/influencing group in performance of a specific task; accepting responsibility for others.

Commercial and Industrial Wiring

Competency Profile

Name: ______________________________

Directions: Evaluate the student using the rating scale below. Write the appropriate number to indicate the degree of competency achieved. The descriptions associated with each of the numbers focus on a level of student performance for each of the tasks listed. The written test scoreline is provided for optional teacher use. It may not be applicable in all cases.

Option A

Rating scale	4 -	Skilled - Can perform job with no additional training.
	3 -	Moderately Skilled - Has performed job during training program; limited additional training may be required.
	2 -	Limited Skill - Has performed job during training program; additional training is required to develop skill.
	1 -	Unskilled - Is familiar with process, but is unable to perform job.
	0 -	No Exposure - No information or practice provided during training program, complete training required.
	NA -	Non-applicable.

Option B

Yes - Can perform with no additional training
No - Is unable to perform satisfactorily

Unit 1: Blueprint Reading and Load Calculations

______1. Construct an electrical blueprint.
______2. Perform load calculations and determine overcurrent protection and conductor size.
______3. Compute lighting loads.
______4. Derate neutral loads.
______5. Determine maximum numbers of conductors in conduit.
______6. Determine wire sizes to prevent voltage drop.
______7. ______________________________

______Written Test Score

Unit 2: Tools and Equipment

______1. Bend, cut, ream, and thread one-half-inch rigid metral conduit.
______2. Bend EMT stub-ups.
______3. Make back-to-back bends on one-half-inch EMT.
______4. Make offset bends on one-half-inch EMT.
______5. Bend and install one-half-inch EMT.
______6. Bend a three-point saddle on one-half-inch EMT.
______7. Bend a four-point saddle on one-half-inch EMT.
______8. Cut, ream, offset, and install connectors on one-half-inch PVC.
______9. ______________________________

______Written Test Score

Competency Profile

Unit 3: Service

______1. Install an overhead raceway with service entrance conductors to a meter base.
______2. Connect a meter base assembly to a load center or panel.
______3. ______________________________

______Written Test Score

Unit 4: Transformers

______1. Locate and list two exceptions on transformer room construction for dry type transformers.
______2. Locate and list two exceptions
______3. Draw a three-phase wye-delta transformer.
______4. Convert amperes to KVA on a three-phase system.
______5. Test transformer turn ratios.
______6. Test transformer insulation resistance.
______7. Connect transformer primary and secondary windings in a delta-wye configuration.
______8. ______________________________

______Written Test Score

Unit 5: Rough-In

______1. Determine the number of conductors allowed to be added to an existing conduit.
______2. Rough in a wood framed wall.
______3. Install outlet boxes on steel rods.
______4. Install outlet boxes on steel studs using caddy metal stud clips.
______5. Install masonry boxes in a block wall.
______6. ______________________________

______Written Test Score

Unit 6: Lighting

______1. Locate articles in the *NEC* concerning lighting requirements.
______2. Change a two-lamp ballast in a fluorescent fixture.
______3. Change sockets in a fluorescent fixture.
______4. Change an HID ballast.
______5. Change a quartz lamp.
______6. ______________________________

______Written Test Score

Competency Profile

Unit 7: Motors and Controllers

_______1. Interpret nameplate information.
_______2. Describe remedies for common motor problems.
_______3. Use the *National Electrical Code* to answer questions about motor control circuits.
_______4. Distinguish between motor starters and contactors.
_______5. Answer questions about uses of contactors and motor starters.
_______6. Disassemble, inspect, and clean a motor.
_______7. Identify run, common, and start terminals on hermetically sealed motors.
_______8. Test capacitors with an ohmmeter.
_______9. Wire a three-phase motor for dual voltages.
_______10. Perform maintenance on a magnetic motor starter or contactor.
_______11. ____

______Written Test Score

Unit 8: Electrical Diagrams and Symbols

_______1. Construct a basic ladder diagram.
_______2. Identify electrical symbols in a wiring diagram.
_______3. ____

______Written Test Score

Unit 9: Two- and Three-Wire Controls

_______1. Complete a ladder and wiring diagram of a two-wire control using a thermal switch.
_______2. Draw a ladder diagram of a three-wire control with an "on" indicating pilot light.
_______3. Draw a ladder and wiring diagram of a three-wire control with an "off" indicating pilot light.
_______4. Determine the number and size of conductors needed to operate a two-wire control system.
_______5. Determine the number and size of conductors needed to operate a three-wire control system.
_______6. Wire a two-wire control.
_______7. Wire two float switches to operate a starter (series connection).
_______8. Wire two float switches to operate a starter (parallel connections).
_______9. Wire a pressure switch to operate a starter with "on" and "off" pilot lights.
_______10. Wire a three-wire control system.
_______11. Wire a multiple station three-wire control.
_______12. Wire a multiple station three-wire control with "on" and "off" pilot lights.
_______13. ____

______Written Test Score

Competency Profile

Unit 10: Separate Control Circuits

______1. Read and interpret ladder diagrams using separate control circuits.
______2. Answer questions dealing with control circuits.
______3. Determine the size and number of conductors needed to operate a separate control circuit.
______4. Wire a relay and a load with a separate control circuit.
______5. Wire a three-phase starter to operate by a separate control circuit.
______6. ______________________________

______Written Test Score

Unit 11: Sequence Control

______1. Answer questions related to a sequence control diagram.
______2. Answer questions related to an auxiliary contact interlocking diagram.
______3. Wire two starters in sequence.
______4. Wire two starters with auxiliary contact interlocking.
______5. ______________________________

______Written Test Score

Unit 12: Jogging Controls

______1. Convert ladder diagrams to wiring diagrams.
______2. Determine the number of conductors needed to operate jogging controls.
______3. Wire a job through a lock-stop push button.
______4. Wire a job through a two-position selector switch.
______5. Wire a job through a two-circuit push button.
______6. Wire a job through a control relay.
______7. ______________________________

______Written Test Score

Unit 13: Reversing Starters

______1. Describe the sequence of operation of ladder diagrams.
______2. Determine the number of conductors needed to operate a reversing control.
______3. Wire a reversing starter with a three-position selector switch.
______4. Wire a reversing starter with one control station using auxiliary contact and mechanical interlock.
______5. Wire a reversing starter with two control stations.
______6. Wire drum switches.
______7. Wire a reversing starter with jog in both directions.
______8. ______________________________

______Written Test Score

Competency Profile

Unit 14: Special Control Circuits

______1. Build a relay control circuit.
______2. Wire a latching relay or contactor.
______3. Wire a timed "on" circuit.
______4. Wire a timed "off" circuit.
______5. Energize three starters in a timed sequential order.
______6. De-energize three starters in a timed sequential order.
______7. Build a ground fault indicator circuit.
______8. ______________________________

______Written Test Score

Unit 15: Programmable Controllers

______1. Match I/O devices with their functions.
______2. Convert between numbering systems.
______3. ______________________________

______Written Test Score

Comments: ______________________________

____

____

____

____

Evaluator: ______________________ Date: ______________

*** Permission to duplicate this profile is granted.**

Commercial and Industrial Wiring

Instructional/Task Analysis

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 1: Blueprint Reading and Load Calculations

1. Terms and definitions
2. Mechanical symbols
3. Plumbing symbols
4. Structural symbols
5. Architectural symbols
6. Electrical symbols
7. Panel, circuit, and other electrical symbols
8. Types of blueprint lines
9. Typical electrical specifications
10. Minimum requirements for electrical devices
11. Determining motor-circuit wire sizes
12. Load calculations
13. Voltage drop
14. Types of blueprints
15. Construct an electrical blueprint
16. Perform load calculations
17. Compute lighting loads
18. Derate neutral loads
19. Determine maximum numbers of conductors in conduit
20. Determine wire sizes to prevent voltage drop

Unit 2: Tools and Equipment

1. Terms and definitions
2. Types of conduit benders
3. Wire termination tools
4. Wire and cable pulling equipment
5. Conduit cutting and threading tools

Instructional/Task Analysis

Unit 2: (Cont.)

Related Information: What the Student Should Know

6. Knockout cutters
7. Power actuated tools
8. Types of excavation equipment

Application: What the Student Should Be Able to Do

9. Bend, cut, ream, and thread ½-inch ridge metal conduit
10. Bend EMT stub-ups
11. Make back-to-back bends on ½-inch EMT
12. Make offset bends on ½-inch EMT
13. Bend and install ½-inch EMT
14. Bend a three-point saddle on ½-inch EMT
15. Bend a four-point saddle on ½-inch EMT
16. Cut, ream, offset, and install connectors on ½-inch PVC

Unit 3: Service

1. Terms and definitions
2. *NEC* requirements for drop clearance and laterals
3. Switch boards and disconnects
4. *NEC* exceptions for overcurrent protection devices
5. Grounding electrodes and ground fault
6. Service entrance devices
7. Emergency and standby systems
8. Procedure for balancing loads

9. Install an overhead raceway with service entrance conductors to a mater base
10. Connect meter base assembly to load center or panel

Instructional/Task Analysis

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 4: Transformers

1. Terms and definitions
2. Basic types of transformers
3. Diagrams of the two most commonly used voltage systems
4. *NEC* requirements for dry type transformers
5. *NEC* requirements for oil-filled transformers
6. *NEC* requirements for askarel-filled transformers
7. Function of a buck and boost transformer
8. Transformer locations
9. Installation and termination of transformers
10. Locate and list two exceptions on transformer room construction for dry type transformers
11. Locate and list two exceptions concerning oil-insulated transformers
12. Draw a three-wire wye-delta transformer
13. Convert amperes to KVA on a three-phase system
14. Test transformer turn ratios
15. Test transformer insulation resistance
16. Connect three transformers in a delta-delta configuration
17. Connect transformer primary and secondary windings in a delta wye configuration

Unit 5: Rough-In

1. Terms and definitions
2. Branch circuit and feeder installation
3. Devices used in special circuit installations
4. Steps for determining the number of conductors allowed in a conduit, based on cross-sectional area
5. Exceptions to the *NEC* requirements for support of flexible metal conduit

Instructional/Task Analysis

Related Information: What the Student Should Know	Application: What the Student Should Be Able to Do
Unit 5: Rough-In	
6. Optional calculations for additional loads to existing installations	7. Determine the number of conductors allowed to be added to an existing conduit
	8. Rough-in a wood framed wall
	9. Install outlet boxes on steel rods
	10. Install outlet boxes on steel studs using caddy metal stud clips for switch boxes
	11. Install masonry boxes in a block wall
Unit 6: Lighting	
1. Terms and definitions	9. Locate articles in the *NEC* concerning lighting requirements
2. Basic types of lighting	10. Change a two lamp ballast in a flourescent fixture
3. Characteristics of incandescent lighting	11. Change sockets in a fluorescent fixture
4. Characteristics of fluorescent lighting	12. Change an HID ballast
5. Characteristics of high intensity discharge lamps	13. Change a quartz lamp
6. Methods of calculating light	
7. Calculating branch circuits and voltage	
8. Switching systems	

Instructional/Task Analysis

Related Information: What the Student Should Know	Application: What the Student Should Be Able to Do

Unit 7: Motors and Controllers

1. Terms and definitions

2. Direct current motor theory of operation

3. Types of DC motors

4. Single-phase motor theory of operation

5. Types of single-phase motors

6. Three-phase motor theory of operation

7. Types of three-phase motors

8. Procedure for reversing a three-phase motor

9. Typical supply voltage for three-phase motors

10. Schematics and terminal connections for delta- and wye-wound three-phase motors

11. Motor problems and their typical symptoms

12. Remedies for motor problems

13. Safety rules to observe when working around motors

14. Types of contactors

15. Parts of a manual contactor

16. Electrical devices or circuits controlled by contactors

Instructional/Task Analysis

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 7: (Cont.)

17. Types of motor starters
18. Types of magnetic motor starters
19. Uses of magnetic motor starters
20. Comparison of parts in magnetic contactors with parts in magnetic motor starters
21. Reasons a contactor cannot be used to control a motor
22. Purposes of a coil assembly
23. Parts of a coil assembly
24. Interpret nameplate information
25. Describe remedies for common motor problems
26. Use the *NEC* to answer questions about motor control circuits
27. Distinguish between motor starters and contactors
28. Answer questions about uses of contactors and motor starters
29. Disassemble, inspect, and clean a motor
30. Identify run, common, and start terminals on hermetically sealed motors
31. Test capacitors with an ohmmeter
32. Wire a three-phase motor for dual voltages
33. Perform maintenance on a magnetic motor starter or contactor

Unit 8: Electrical Diagrams and Symbols

1. Terms and definitions
2. Characteristics of wiring diagrams
3. Characteristics of ladder diagrams
4. Characteristics of one-line diagrams
5. Wiring and ladder diagram symbols
6. Major steps in constructing a ladder
7. Construct a basic ladder diagram
8. Identify electrical symbols in a wiring diagram

Instructional/Task Analysis

Unit 9: Two and Three Wire Controls

Related Information: What the Student Should Know

1. Terms and definitions
2. Typical two-wire pilot devices
3. Advantages of two-wire controls
4. Basic rule for three-wire controls
5. Advantages of three-wire controls
6. Operation of a two-wire control system
7. Operation of a three-wire control system

Application: What the Student Should Be Able to Do

8. Complete a ladder and a wiring diagram of a two-wire control using a thermal switch
9. Draw a ladder diagram of a three-wire control with an "on" indicating pilot light
10. Draw a ladder and a wiring diagram of a three-wire control with an "off" indicating pilot light
11. Determine the number and size of conductors needed to operate a two-wire control system
12. Determine the number and size of conductors needed to operate a three-wire control system
13. Wire a two-wire control
14. Wire two float switches to operate a starter (series connection)
15. Wire two float switches to operate a starter (parallel series)
16. Wire a pressure switch to operate a starter with "on" and "off" pilot lights
17. Wire a three-wire control system
18. Wire a multiple station three-wire control
19. Wire a multiple station three-wire control with "on" and "off" pilot lights

Instructional/Task Analysis

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 10: Separate Control Circuits

1. Terms and definitions
2. Reasons for separate control circuits
3. Applications for separate control circuits
4. Sources of separate control circuits
5. Typical control transformer schematics and their voltage ratings
6. Necessary changes that must be made to a starter when using a separate control circuit
7. Read and interpret ladder diagrams using separate control circuits
8. Answer questions dealing with control circuits
9. Determine the size and number of conductors needed to operate a separate control circuit
10. Wire a relay and a load with a separate control circuit
11. Wire a three-phase starter to operate by a separate control circuit

Unit 11: Sequence Control

1. Terms and definitions
2. Purpose of sequence control
3. Advantages of sequence control
4. Uses of sequence control
5. Purpose of auxiliary contact interlocking
6. Advantages of auxiliary contact interlocking
7. Uses of auxiliary contact interlocking
8. Answer questions related to a sequence control diagram
9. Answer questions related to an auxiliary contact interlocking diagram
10. Wire two starters in sequence
11. Wire two starters with auxiliary contact interlocking

Unit 12: Jogging Controls

1. Jogging
2. Methods of jogging control
3. Advantages of jogging control

Instructional/Task Analysis

Related Information: What the Student Should Know	Application: What the Student Should Be Able to Do
Unit 12: (Cont.)	
4. Sequence of operation of three ladder diagrams	5. Convert ladder diagrams to wiring diagrams 6. Determine the number of conductors needed to operate jogging controls 7. Wire a jog through a lock-stop push button 8. Wire a jog through a two-position selector switch 9. Wire a jog through a two-circuit push button 10. Wire a jog through a control relay
Unit 13: Reversing Starters	
1. Terms and definitions 2. Types of reversing starter construction 3. Types of interlocking methods for reversing starters 4. Types of drum controls 5. Drum switch diagram	6. Describe the sequence of operation of ladder diagrams 7. Determine the number of conductors needed to operate a reversing control 8. Wire a reversing starter with a three-position selector switch 9. Wire a reversing starter with one control station using auxiliary contact and mechanical interlock 10. Wire a reversing starter with one control station using push button interlock and auxiliary contact interlock 11. Wire a reversing starter with two control stations 12. Wire drum switches

Instructional/Task Analysis

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 13: (Cont.)

13. Wire a reversing starter with jog in both directions

Unit 14: Special Control Circuits

1. Terms and definitions
2. Parts of a control relay
3. Uses for control relays
4. Parts of a latching relay
5. Reason for using latching relays or contactors
6. Types of timing relays
7. Applications for timing relays
8. How a ground fault indicator works
9. Use of an alarm silencing circuit

10. Build a relay control circuit
11. Wire a latching relay or contactor
12. Wire a timed "on" circuit
13. Wire a timed "off" circuit
14. Energize three starters in a timed sequential order
15. De-energize three starters in a timed sequential order
16. Build a ground fault indicator circuit

Unit 15: Programmable Controls

1. Terms and definitions
2. Programmable controller functions
3. Three stages necessary to control a process
4. Input devices
5. Output devices
6. Components of a programmable controller
7. States of contacts

Instructional/Task Analysis

Related Information: What the Student Should Know

Unit 15: (Cont.)

8. Types of I/O modules
9. Parts of an optical coupler
10. Basic PC ladder logic symbols
11. Why a stop button is wired normally closed
12. Basic numbering systems used in programmable controllers

Application: What the Student Should Be Able to Do

13. Match I/O devices with their functions
14. Convert between numbering systems

Related Academic and Workplace Skills For *Commercial and Industrial Wiring*

Task	Skill Group	Sub Skill	Description
Unit 1: Blueprint Reading and Load Calculations			
Construct an electrical blueprint (A.S. 1)	Foundation Skills	Reading	Applies technical information derived from print materials; applies information to new situation
	Adaptability Skills	Creative thinking	Creates new design by applying knowledge gained in information sheet
Perform load calculations and determine overcurrent protection and conductor size (A.S. 2)	Foundation Skills	Reading	Analyzes and applies what has been read to specific task; uses diagram to obtain necessary information to perform calculations
		Math	Applies computation skills (addition, subtraction, multiplication, division) as used on job; interprets tables
Compute lighting loads (A.S. 3)	Foundation Skills	Reading	Applies technical information derived from print materials; uses tables to obtain necessary information to perform calculations
		Math	Applies computation skills as used on job; interprets tables
Derate neutral loads (A.S. 4)	Foundation Skills	Reading	Applies technical information derived from print materials; uses tables to obtain necessary information to perform calculations
		Math	Applies computation skills (addition, subtraction, multiplication, division) as used on job; calculates percentages
Determine maximum number of conductors in conduit (A.S. 5)	Foundation Skills	Reading	Analyzes and applies what has been read to specific task
Determine wire sizes to prevent voltage drop (A.S. 6)	Foundation Skills	Reading	Analyzes and applies what has been read to specific task; applies information to new situation
		Math	Computes using a formula; applies computation skills (addition, subtraction, multiplication, division) as used on job

Related Academic and Workplace Skills

Task	Skill Group	Sub Skill	Description
Unit 2: Tools and Equipment			
Bend, cut, ream, and thread one-half-inch rigid metal conduit (J.S. 1)	Foundation Skills	Reading	Comprehends written specifications and applies them to a task; understands technical words; follows written directions
		Math	Makes accurate measurements using measuring tape
Bend EMT stub-ups (J.S. 2)	Foundation Skills	Reading	Comprehends written specifications and applies them to a task; understands technical words; follows written directions
		Math	Makes accurate measurements using measuring tape; applies computation skills (addition, subtraction, multiplication, division) as used on job
Make back-to-back bends on one-half-inch EMT (J.S. 3)	Foundation Skills	Reading	Comprehends written specifications and applies them to a task; understands technical words; follows written directions
		Math	Makes accurate measurements using measuring tape; operates technical equipment to reach mathematical conclusion (proper bend)
Make offset bends on one-half-inch EMT (J.S. 4)	Foundation Skills	Reading	Comprehends written specifications and applies them to a task; understands technical words; follows written directions
		Math	Makes accurate measurements using measuring tape; applies computation skills (addition, subtraction, multiplication, division) as used on job; operates technical equipment to reach mathematical conclusions (proper degree of bend)
Bend and install one-half-inch EMT (J.S. 5)	Foundation Skills	Reading	Comprehends written specifications and applies them to a task; understands technical words; follows written directions

Related Academic and Workplace Skills

Task	Skill Group	Sub Skill	Description
Unit 2: (Cont.)			
		Math	Makes accurate measurements using measuring tape; applies computation skills (addition, subtraction, multiplication, division) as used on job; operates technical equipment to reach mathematical conclusions (proper degree of bend)
Bend a three-point saddle on one-half-inch EMT (J.S. 6)	Foundation Skills	Reading	Comprehends written specifications and applies them to a task; understands technical words; follows written directions
		Math	Makes accurate measurements using measuring tape; applies computation skills (addition, subtraction, multiplication, division) as used on job; operates technical equipment to reach mathematical conclusions (proper degree of bend); makes calculations using common fractions
Bend a four-point saddle on one-half-inch EMT (J.S. 7)	Foundation Skills	Reading	Comprehends written specifications and applies them to a task; understands technical words; follows written directions
		Math	Makes accurate measurements using measuring tape; applies computation skills (addition, subtraction, multiplication, division) as used on job; operates technical equipment to reach mathematical conclusions (proper degree of bend)
Cut, ream, offset, and install connectors on one-half-inch PVC (J.S. 8)	Foundation Skills	Reading	Comprehends written specifications and applies them to a task; understands technical words; follows written directions
		Math	Makes accurate measurements using measuring tape; applies computation skills (addition, subtraction, multiplication, division) as used on job; operates technical equipment to reach mathematical conclusions (proper degree of bend)

Related Academic and Workplace Skills

Task	Skill Group	Sub Skill	Description
Unit 3: Service			
Install an overhead raceway with service entrance conductors to a meter base (J.S. 1)	Foundation Skills	Reading	Uses appropriate materials and techniques as specified; understands technical words; follows written directions
		Math	Makes accurate measurements using a folding rule with sliding scale; applies computation skills (addition, subtraction, multiplication, division) as used on job
Connect a meter base assembly to a load center or panel (J.S. 2)	Foundation Skills	Reading	Uses appropriate materials and techniques as specified; understands technical words; follows written directions
		Math	Makes accurate measurements using a folding rule; makes rough measurements
Unit 4: Transformers			
Locate and list two exceptions on transformer room construction for dry type transformers (A.S. 1)	Foundation Skills	Reading	Comprehends written specifications and determines what information is needed
Locate and list two exceptions concerning oil-insulated transformers (A.S. 2)	Foundation Skills	Reading	Comprehends written specifications and determines what information is needed
Draw a three-phase wye-delta transformer (A.S. 3)	Foundation Skills	Reading	Analyzes and applies what has been read to a specific task
	Adaptability Skills	Creative thinking	Creates technical illustration using proper symbols
Convert amperes to KVA on a three-phase system (A.S. 4)	Foundation Skills	Math	Converts units of measure
Test transformer turn ratios (J.S. 1)	Foundation Skills	Reading	Applies information to job performance; reads instruments; follows written directions
		Writing	Records instrument readings
		Math	Calculates ratios; applies computation skills as they are actually used on the job

Related Academic and Workplace Skills

Task	Skill Group	Sub Skill	Description
Unit 4: (Cont.)			
Test transformer insulation resistance (J.S. 2)	Foundation Skills	Reading	Applies information to job performance; reads instruments; follows written directions
		Writing	Records instrument readings
		Math	Measures in metric units
Connect transformer primary and secondary windings in a delta-wye configuration (J.S. 3)	Foundation Skills	Reading	Applies information to job performance; reads instruments; follows written directions
		Writing	Records instrument readings
Unit 5: Rough-In			
Determine the number of conductors allowed to be added to an existing conduit (A.S. 1)	Foundation Skills	Reading	Uses standard occupational resource materials; follows written directions
		Math	Interprets tables; calculates percentages, ratios, decimals; applies computation skills as they are actually used on the job
Rough in a wood framed wall (J.S. 1)	Foundation Skills	Reading	Uses blueprints to obtain factual information; uses standard occupational resource materials; follows written directions
		Math	Makes precision measurements using measuring device
Install outlet boxes on steel rods (J.S. 2)	Foundation Skills	Reading	Uses standard occupational resource materials; applies information to job performance; follows written directions
Install outlet boxes on steel studs using caddy metal stud clips for switch boxes (J.S. 3)	Foundation Skills	Reading	Uses standard occupational resource materials; follows written directions
Install masonry boxes in a block wall (J.S. 4)	Foundation Skills	Reading	Uses blueprint to obtain factual information; uses standard occupational resource materials; follows written directions

Related Academic and Workplace Skills

Task	Skill Group	Sub Skill	Description
Unit 5: (Cont.)			
		Math	Makes precision measurements using measuring device; uses basic geometric principles - 90° angles
Unit 6: Lighting			
Locate articles in the *NEC* concerning lighting requirements (A.S. 1)	Foundation Skills	Reading	Uses standard occupational resource materials; determines what information is needed
Change a two-lamp ballast in a fluorescent fixture (J.S. 1)	Foundation Skills	Reading	Uses standard occupational resource materials; applies information to job performance; follows written directions
Change sockets in a fluorescent fixture (J.S. 2)	Foundation Skills	Reading	Uses standard occupational resource materials; applies information to job performance; follows written directions
Change an HID ballast (J.S. 3)	Foundations Skills	Reading	Uses standard occupational resource materials; applies information to job performance; follows written directions
Change a quartz lamp	Foundation Skills	Reading	Uses standard occupational resource materials; applies information to job performance; follows written directions
Unit 7: Motors and Controllers			
Interpret nameplate information (A.S. 1)	Foundation Skills	Reading	Comprehends written information; determines what information is needed; draws conclusions from what is read
		Writing	Presents answers in a clear and understandable form
	Adaptability Skills	Problem solving	Demonstrates logical reasoning in reaching a conclusion
Describe remedies for common motor problems (A.S. 2)	Foundation Skills	Reading	Analyzes and applies what has been read to specific task; follows written directions
		Writing	Presents answers in a clear and understandable form
	Adaptability Skills	Problem solving	Demonstrates logical reasoning in reaching a conclusion; gives solutions

Related Academic and Workplace Skills

Task	Skill Group	Sub Skill	Description
Unit 7: (Cont.)			
Use the *National Electrical Code* to answer questions about motor control circuits (A.S. 3)	Foundation Skills	Reading	Uses standard occupational resource materials; determines what information is needed; draws conclusions from what is read
		Writing	Presents answers in a clear and understandable form
Distinguish between motor starters and contactors (A.S. 4)	Foundation Skills	Reading	Interprets drawings to obtain factual information; recalls important details from written information
		Writing	Presents answers/conclusions in a clear and understandable form
	Adaptability Skills	Problem solving	Demonstrates logical reasoning in reaching a conclusion
Answer questions about uses of contactors and motor starters (A.S. 5)	Foundation Skills	Reading	Comprehends written information for main ideas; recalls important details from written information
		Writing	Presents answers/conclusions in a clear and understandable form
	Adaptability Skills	Problem solving	Demonstrates logical reasoning in reaching a conclusion
Disassemble, inspect, and clean a motor (J.S. 1)	Foundation Skills	Reading	Analyzes and applies what has been read to specific task; understands technical words; follows written directions
Identify run, common, and start terminals on hermetically sealed motors (J.S. 2)	Foundation Skills	Reading	Reads and follows instructions to perform tests; reads instruments; analyzes what has been read to specific task
		Writing	Records instrument readings
	Adaptability Skills	Problem solving	Creates technical illustration using proper symbols
		Problem solving	Demonstrates logical reasoning in reaching a conclusion

Related Academic and Workplace Skills

Task	Skill Group	Sub Skill	Description
Unit 7: (Cont.)			
Test capacitors with an ohmmeter (J.S. 3)	Foundation Skills	Reading	Applies information to job performance; reads instruments; follows written directions
	Adaptability Skills	Problem solving	Draws conclusions from tests
Wire a three-phase motor for dual voltages (J.S. 4)	Foundation Skills	Reading	Uses appropriate materials and techniques as specified; understands technical words; follows written directions
Perform maintenance on a magnetic motor starter or contactor (J.S. 5)	Foundation Skills	Reading	Uses appropriate materials and techniques as specified; understands technical words; follows written directions
Unit 8: Electrical Diagrams and Symbols			
Construct a basic ladder diagram (A.S. 1)	Foundation Skills	Reading	Recalls important details from written information; follows written directions
	Adaptability Skills	Problem solving	Creates technical illustration using proper symbols
Identify electrical symbols in a wiring diagram (A.S. 2)	Foundation Skills	Reading	Interprets symbols on technical illustration; follows written directions
		Writing	Prints/writes legibly
Unit 9: Two- and Three-Wire Controls			
Complete a ladder and a wiring diagram of a two-wire control using a thermal switch (A.S. 1)	Foundation Skills	Reading	Recalls important details from written information; follows written directions
	Adaptability Skills	Problem solving	Creates technical illustration using proper symbols
Draw a ladder diagram of a three-wire control with an "on" indicating pilot light (A.S. 2)	Foundation Skills	Reading	Recalls important details from written information; follows written directions
	Adaptability Skills	Problem solving	Converts one idea to another; creates technical illustration using proper symbols
Draw a ladder and a wiring diagram of a three-wire control with an "off" indicating pilot light (A.S. 3)	Foundation Skills	Reading	Recalls important details from written information; follows written directions
	Adaptability Skills	Creative thinking	Creates technical illustrations using proper symbols

Related Academic and Workplace Skills

Task	Skill Group	Sub Skill	Description
Unit 9: (Cont.)			
Determine the number and size of conductors needed to operate a two-wire control system (A.S. 4)	Foundation Skills	Reading	Uses standard occupational resource materials; determines what information is needed; interprets drawings to obtain factual information
		Writing	Records data from drawing and resource material
Determine the number and size of conductors needed to operate a three-wire control system (A.S. 5)	Foundation Skills	Reading	Uses standard occupational resource materials; determines what information is needed; interprets drawings to obtain factual information
		Writing	Records data from drawing and resource material
Wire a two-wire control (J.S. 1)	Foundation Skills	Reading	Uses appropriate materials and techniques as specified; understands technical words; follows written directions
		Writing	Writes logical and understandable sentences; organizes information in logical sequence; writes/prints legibly
	Adaptability Skills	Problem solving	Creates technical illustration using proper symbols
Wire two float switeches to operate a starter (series connection) (J.S. 2)	Foundation Skills	Reading	Uses appropriate materials and techniques as specified; understands technical words; follows written directions
		Writing	Writes logical and understandable sentences; organizes information in logical sequence; writes/prints legibly
	Adaptability Skills	Problem solving	Creates technical illustration using proper symbols
Wire two float switches to operate a starter (parallel connections) (J.S. 3)	Foundation Skills	Reading	Uses appropriate materials and techniques as specified; understands technical words; follows written directions
		Writing	Writes logical and understandable sentences; organizes information in logical sequence; writes/prints legibly
	Adaptability Skills	Problem solving	Creates technical illustration using proper symbols

Related Academic and Workplace Skills

Task	Skill Group	Sub Skill	Description
Unit 9: (Cont.)			
Wire a pressure switch to operate a starter with "on" and "off" pilot lights (J.S. 4)	Foundation Skills	Reading	Uses appropriate materials and techniques as specified; understands technical words; follows written directions
		Writing	Writes logical and understandable sentences; organizes information in logical sequence; writes/prints legibly
	Adaptability Skills	Problem solving	Creates technical illustration using proper symbols
Wire a three-wire control system (J.S. 5)	Foundation Skills	Reading	Uses appropriate materials and techniques as specified; understands technical words; follows written directions
		Writing	Writes logical and understandable sentences; organizes information in logical sequence; writes/prints legibly
	Adaptability Skills	Problem solving	Creates technical illustration using proper symbols
Wire a multiple station three-wire control (J.S. 6)	Foundation Skills	Reading	Uses appropriate materials and techniques as specified; understands technical words; follows written directions
		Writing	Writes logical and understandable sentences; organizes information in logical sequence; writes/prints legibly
	Adaptability Skills	Problem solving	Creates technical illustration using proper symbols
Wire a multiple station three-wire control with "on" and "off" pilot lights (J.S. 7)	Foundation Skills	Reading	Uses appropriate materials and techniques as specified; understands technical words; follows written directions
		Writing	Writes logical and understandable sentences; organizes information in logical sequence; writes/prints legibly
	Adaptability Skills	Problem solving	Creates technical illustration using proper symbols

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Related Academic and Workplace Skills

Task	Skill Group	Sub Skill	Description
Unit 10: Separate Control Circuits			
Read and interpret ladder diagrams using separate control circuits (A.S. 1)	Foundation Skills	Reading	Interprets drawing to obtain factual information; determines what information is needed
		Writing	Writes logical and understandable sentences; organizes information in logical sequence
Answer questions dealing with control circuits (A.S. 2)	Foundation Skills	Reading	Uses standard occupational resource materials; determines what information is needed
		Writing	Presents answers in a clear and understandable form
Determine the size and number of conductors needed to operate a separate control circuit (A.S. 3)	Foundation Skills	Reading	Uses standard occupational resource materials; determines what information is needed; interprets drawings to obtain factual information
		Writing	Records data from drawing and resource material
Wire a relay and a load with a separate control circuit (J.S. 1)	Foundation Skills	Reading	Uses appropriate materials and techniques as specified; understands technical words; follows written directions
		Writing	Writes logical and understandable sentences; organizes information in logical sequence; writes/prints legibly
	Adaptability Skills	Problem solving	Creates technical illustration using proper symbols
Wire a three-phase starter to operate by a separate control circuit (J.S. 2)	Foundation Skills	Reading	Uses appropriate materials and techniques as specified; understands technical words; interprets drawing to obtain factual information; follows written directions
		Writing	Writes logical and understandable sentences; organizes information in logical sequence; writes/prints legibly

Related Academic and Workplace Skills

Task	Skill Group	Sub Skill	Description
Unit 11: Sequence Control			
Answer questions related to sequence control diagram (A.S. 1)	Foundation Skills	Reading	Comprehends written information for main ideas; interprets technical drawing to obtain factual information; determines what information is needed
		Writing	Presents answers in a clear and understandable form; writes/prints legibly
Answer questions related to an auxiliary contact interlocking diagram (A.S. 2)	Foundation Skills	Reading	Comprehends written information for main ideas; interprets technical drawing to obtain factual information; determines what information is needed
		Writing	Presents answers in a clear and understandable form; writes/prints legibly
Wire two starters in sequence (J.S. 1)	Foundation Skills	Reading	Uses appropriate materials and techniques as specified; understands technical words; follows written directions
		Writing	Writes logical and understandable sentences; organizes information in a logical sequence; writes/prints legibly
	Adaptability Skills	Problem solving	Creates technical illustration using proper symbols
Wire two starters with auxiliary contact interlocking (J.S. 2)	Foundation Skills	Reading	Uses appropriate materials and techniques as specified; understands technical words; follows written directions
		Writing	Writes logical and understandable sentences; organizes information in a logical sequence; writes/prints legibly
	Adaptability Skills	Problem solving	Creates technical illustration using proper symbols

Related Academic and Workplace Skills

Task	Skill Group	Sub Skill	Description
Unit 12: Jogging Controls			
Convert ladder diagrams to wiring diagrams (A.S. 1)	Foundation Skills	Reading	Interprets drawings to obtain factual information; follows written directions
	Adaptability Skills	Problem solving	Creates technical illustration using proper symbols
Determine the number of conductors needed to operate jogging controls (A.S. 2)	Foundation Skills	Reading	Uses standard occupational resource materials; determines what information is needed; interprets drawings to obtain factual information
		Writing	Records data from drawings and resource material
Wire a jog through a lock-stop push button (J.S. 1)	Foundation Skills	Reading	Uses appropriate materials and techniques as specified; understands technical words; follows written directions
		Writing	Writes logical and understandable sentences; organizes information in logical sequence; writes/prints legibly
	Adaptability Skills	Problem solving	Creates technical illustrations using proper symbols
Wire a jog through a two-position selector (J.S. 2)	Foundation Skills	Reading	Uses appropriate materials and techniques as specified; understands technical words; follows written directions
		Writing	Writes logical and understandable sentences; organizes information in logical sequence; writes/prints legibly
	Adaptability Skills	Problem solving	Creates technical illustrations using proper symbols
Wire a jog through a two-circuit push button (J.S. 3)	Foundation Skills	Reading	Uses appropriate materials and techniques as specified; understands technical words; follows written directions
		Writing	Writes logical and understandable sentences; organizes information in logical sequence; writes/prints legibly
	Adaptability Skills	Problem solving	Creates technical illustrations using proper symbols

Related Academic and Workplace Skills

Task	Skill Group	Sub Skill	Description
Unit 12: (Cont.)			
Wire a jog through a control relay (J.S. 4)	Foundation Skills	Reading	Uses appropriate materials and techniques as specified; understands technical words; follows written directions
		Writing	Writes logical and understandable sentences; organizes information in logical sequence; writes/prints legibly
	Adaptability Skills	Problem solving	Creates technical illustrations using proper symbols
Unit 13: Reversing Starters			
Describe the sequence of operation of ladder diagrams (A.S. 1)	Foundation Skills	Reading	Interprets drawings to obtain factual information; follows written directions
		Writing	Writes logical and understandable sentences; organizes information in logical sequence
Determine the number of conductors needed to operate a reversing control (A.S. 2)	Foundation Skills	Reading	Uses standard occupational resource materials; determines what information is needed; interprets drawings to obtain factual information
		Writing	Records data from drawing and resource material
Wire a reversing starter with a three-position selector switch (J.S. 1)	Foundation Skills	Reading	Uses appropriate materials and techniques as specified; understands technical words; follows written directions
		Writing	Writes logical and understandable sentences; organizes information in logical sequence; writes/prints legibly
	Adaptability Skills	Problem solving	Creates technical illustrations using proper symbols

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Related Academic and Workplace Skills

Task	Skill Group	Sub Skill	Description
Unit 13: (Cont.)			
Wire a reversing starter with one control station using auxiliary contact and mechanical interlock (J.S. 2)	Foundation Skills	Reading	Uses appropriate materials and techniques as specified; understands technical words; follows written directions
		Writing	Writes logical and understandable sentences; organizes information in logical sequence; writes/prints legibly
	Adaptability Skills	Problem solving	Creates technical illustrations using proper symbols
Wire a reversing starter with one control station using push-button and auxiliary contact interlocking (J.S. 3)	Foundation Skills	Reading	Uses appropriate materials and techniques as specified; understands technical words; follows written directions
		Writing	Writes logical and understandable sentences; organizes information in logical sequence; writes/prints legibly
	Adaptability Skills	Problem solving	Creates technical illustrations using proper symbols
Wire a reversing starter with two control stations (J.S. 4)	Foundation Skills	Reading	Uses appropriate materials and techniques as specified; understands technical words; follows written directions
		Writing	Writes logical and understandable sentences; organizes information in logical sequence; writes/prints legibly
	Adaptability Skills	Problem solving	Creates technical illustrations using proper symbols
Wire drum switches (J.S. 5)	Foundation Skills	Reading	Uses appropriate materials and techniques as specified; understands technical words; follows written directions
		Writing	Writes logical and understandable sentences; organizes information in logical sequence; writes/prints legibly
	Adaptability Skills	Problem solving	Creates technical illustrations using proper symbols

Related Academic and Workplace Skills

Task	Skill Group	Sub Skill	Description
Unit 13: (Cont.)			
Wire a reversing starter with jog in both directions (J.S. 6)	Foundation Skills	Reading	Uses appropriate materials and techniques as specified; understands technical words; follows written directions
		Writing	Writes logical and understandable sentences; organizes information in logical sequence; writes/prints legibly
	Adaptability Skills	Problem solving	Creates technical illustrations using proper symbols
Unit 14: Special Control Circuits			
Build a relay control circuit (J.S. 1)	Foundation Skills	Reading	Analyzes and applies what has been read to specific task; applies information to job performance; follows written directions
		Writing	Writes logical and understandable sentences; organizes information in logical sequence
	Adaptability Skills	Creative thinking	Creates new designs by applying criteria specified in scenario
		Problem solving	Demonstrates logical reasoning in reaching a conclusion; implements strategy to complete task
Wire a latching relay or contactor (J.S. 2)	Foundation Skills	Reading	Interprets drawings to obtain factual information; follows written directions
	Adaptability Skills	Problem solving	Demonstrates logical reasoning in reaching a conclusion; implements strategy to complete task
Wire a timed "on" circuit (J.S. 3)	Foundation Skills	Reading	Interprets drawings to obtain factual information; applies information to job performance; follows written directions
		Writing	Writes logical and understandable sentences; organizes information in logical sequence
	Adaptability Skills	Problem solving	Demonstrates logical reasoning in reaching a conclusion; implements strategy to complete task

Related Academic and Workplace Skills

Task	Skill Group	Sub Skill	Description
Unit 14: (Cont.)			
Wire a timed "off" circuit (J.S. 4)	Foundation Skills	Reading	Interprets drawings to obtain factual information; applies information to job performance; follows written directions
		Writing	Writes logical and understandable sentences; organizes information in logical sequence
	Adaptability Skills	Problem solving	Demonstrates logical reasoning in reaching a conclusion; implements strategy to complete task
Energize three starters in a timed sequential order (J.S. 5)	Foundation Skills	Reading	Analyzes and applies what has been read to specific task; applies information to job performance; follows written directions
		Writing	Writes logical and understandable sentences; organizes information in logical sequence
	Adaptability Skills	Creative thinking	Creates new design by applying criteria specified in procedure
		Problem solving	Demonstrates logical reasoning in reaching a conclusion; implements strategy to complete task
De-energize three starters in a timed sequential order (J.S. 6)	Foundation Skills	Reading	Analyzes and applies what has been read to specific task; applies information to job performance; follows written directions
		Writing	Writes logical and understandable sentences; organizes information in logical sequence
	Adaptability Skills	Creative thinking	Creates new design by applying criteria specified in procedure
		Problem solving	Demonstrates logical reasoning in reaching a conclusion; implements strategy to complete task

Related Academic and Workplace Skills

Task	Skill Group	Sub Skill	Description
Unit 14: (Cont.)			
Build a ground fault indicator circuit (J.S. 7)	Foundation Skills	Reading	Analyzes and applies what has been read to specific task; applies information to job performance; follows written directions
	Adaptability Skills	Creative thinking	Creates new design by applying criteria specified in procedure
		Problem solving	Demonstrates logical reasoning in reaching a conclusion; implements strategy to complete task
Unit 15: Programmable Controllers			
Match I/O devices with their functions (A.S. 1)	Foundation Skills	Reading	Applies information and concepts derived from printed materials; follows written directions
Convert between numbering systems (A.S. 2)	Foundation Skills	Reading	Analyzes and applies what has been read to specific task; follows written directions
		Math	Converts binary and decimal numbers

Commercial and Industrial Wiring

Tools, Equipment, and Materials List

Awl
Ball peen hammer
Beam, 2" x 4"
Bleeder resistor
Box clips
Boxes, 1900
Capacitorr, start or run
Center punch
Clean rags
Combination wrench set
Compressed air
Compressor units, hermetically sealed
Conduit pipe die
Construction blueprint
Control transformer
Copper, #2 and #4
Cutting oil
Drum switch
Dual voltage motor
EMT bender
EMT couplings and connectors
Flatblade screwdriver
Float switch
Folding rule with sliding scale
Framed wall with 2" x 4" studs
Fuses
Fuse block
Fuse holders
Gear puller
Hacksaw
Hammer
Hanger bar, expandable
Hanger box
Hickey's pipe vise
HID ballast
Insulating bushings, 1/2"
Knife
Lamp
Latching relay, 4-pole
Level
Line pliers
Locknuts,, 1 1/4"
Lock-stop device
Machine oil
Magnetic coils
Marking pencil
Measuring tape
Megger tester
Metal stud clip
Meter base, 3
Mock up wall
Motor cleaning fluid
Mounting board
Mounting nails
Needle-nosed pliers
Normally closed push button
Normally open push button
Octagon box
Ohmmeter
One-hole straps, 1/2"
Outlet boxes
Paper
Pencil
Pilot light, 120 volt
Pipe straps, 2"
Plaster ring
Polishing cloth
Pouch tools
Power supply
Pressure switch
PVC bender
PVC cement
PVC connectors
Quartz lamp
Reamed nipple, 1 1/4"
Reaming tool
Relay, 4-pole
Republic bender
Reversing starter
Rigid conduit strap, 1 1/2"
Rigid metal conduit
Rod hanger clamps
Rule
Safety glasses
Screwdriver set
Service entrance cap
Setscrew connectors and couplings
Sheet metal screws
Small socket wrench set
Soft-faced hammer
Split-phase motor
Square outlet boxes

Tools, Equipment, and Materials List

Start/stop station
Stove bolt
Switch boxes, masonry
Test jumpers
Thermometer
THHN, white, black, blue, and red
Three-element control station
Three phase open starter
Three-position selector switch
THWN, #16
Time clock, 24 hour
Transformers
Two-element control station
Two-lamp ballast
Voltmeter
Wire
Wire brush
Wire markers
Wire nuts

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Glossary

A

Accelerating contactors — Contactors or relays used in starting motors at low speed, then increasing to maximum speed in preset timed steps

Across-the-line — Method of starting an electric motor by connecting it directly to supply line

Ambient temperature — The temperature in the area where the transformer is to be located. High temperatures will raise the insulation temperatures and shorten the life of the transformer. The KVA rating should be derated .4% for each 1°C over 30°C average ambient temperature for 150°C insulation

Ampacity — The current in amperes that a conductor can carry continuously under the conditions of use without exceeding its temperature rating

Analog signal — A signal that varies proportionally with some aspect of the environment; the signal from a pressure transducer which varies with the amount of pressure being applied

Arc chute — Partition between contacts to reduce electrical arcing

Armature — Portion of coil assembly moved by magnetism

Automatic starting — Pertaining to self-acting starter completely controlled by pilot switches or some other sensing device

Auxiliary contact — Contact provided in addition to the main circuit contacts but operated with the main contacts; set of normally open auxiliary contacts on a starter, contactor, or relay that close when main contacts close, providing a means of sealing or holding the circuit in the energized state; can be N/O or N/C

B

B — Blue lamp

Backhoe — Machine used to dig ditches on construction sites

Ballast — Transformer used in lighting circuits

Bender — Used to bend pipe used in electrical trades

Bimetal — Two different metals bonded to provide fast heat transfer to trip contacts by mechanical deflection

Blueprint — Copy of the original detailed drawings of a structure

Blueprint lines — Set of conventional symbols to depict an object

Branch circuit — The circuit that extends from the last overcurrent protection device to the outlets

Buck and boost transformer — A transformer that increases or decreases voltage

C

Cable bender — Mechanical or hydraulic device used to bend heavy conductors in panels and junction boxes

Cable cutters — Used to cut conductors

Cathode — Coiled coil or triple coil tungsten wire at each end of lamp which is coated with material that emits electrons

Coefficient — The square root of the ratio of the power reflected from a surface to the power incident of the same surface

Color coding — Assigning colors to conductors based on their uses

Contactor — Device used to make or break a motor's power circuit

Control transformer — Small transformer used to step supply voltage down to appropriate control voltage

Copper-clad aluminum — Aluminum conductor with an outer coating of copper metallurgically bonded to the aluminum core

Counter — A logic element in a PC user program that is used to simulate the operation of electromechanical counters

Covered — Conductor encased within material of composition and thickness not recognized by the *National Electrical Code* as electrical insulation

Cross phasing — Unintentional contact of two or more electrical phases; results in a short circuit

Cross-sectional area — Area in square inches allowed in a raceway; area required for conductors in a conduit or tubing

CT — Current transformer

Cutting tools — Used to cut conduit for electrical installations

CW — Cool white lamp

D

D — Daylight lamp

Delta — Three-phase circuit in which the windings are connected in series to form a closed loop

Demand factor — The ratio of the maximum demand of a system, or part of a system, to the total connected load of a system or the part of the system under consideration

Disconnects — Devices used for breaking a circuit which may be fused or unfused

Discrete — A two-state reference in the user program that can be either on or off

Down stream — Coming after; following other devices or events

Drop chain — Short length of small chain used to pull conductors or flexible conduit through an enclosed space or wall cavity

Drum switch — A switch having electrical connecting parts in the form of fingers held by spring pressure against contact segments or the surface of a rotating cylinder

Dual voltage motor — Motor capable of being wired to run at two different voltages

E

Equipment grounding conductor — Conductor used to connect non-current carrying metal parts of equipment to the system-grounded conductor or grounding-electrode conductor

F

FC — Footcandles

Feeder circuit — All circuit conductors between the service equipment of the source of a separately derived system and final branch circuit overcurrent device

Fiber optics — Transfer of discrete signals through glass fibers with light

Fish — Establishing a connection between two points so a cable or length of flexible conduit can be installed

Fish tape — Long tape of steel, nylon, or other material used to push or pull conductors into a raceway

Fluorescent lighting — Electric discharge lighting

Full voltage control — Function of magnetic control that connects equipment directly to supply line on starting

G

G — Green lamp

Ground — Any good conductor that is connected to a common chassis with zero relative voltage

Grounded — Connected to the earth or to some conducting body that serves in place of the earth

Grounded conductor — System or circuit conductor that is intentionally grounded

Grounding-electrode conductor — Conductor used to connect grounding electrode to the equipment grounding conductor or to grounding conductor of circuit at service equipment or at source of separately derived system

H

Hammer drill — Used to bore through concrete

HID — High intensity discharge

I

Incandescent lighting — Consists of a filament which is a highly refractory conductor mounted in a transparent or translucent glass bulb

Indicating pilot light — Small light that indicates status of controls or machinery

Input — A signal that provides the controller information about the system; can be discrete, numeric, or analog

Insulated — Conductor encased within material of composition and thickness recognized by the *National Electrical Code* as electrical insulation

Interlocking — Interrelating with other controllers; a device is connected in such a way that the operation of one part controls the operation of another

Isolating transformer — Insulates the primary circuit from the secondary circuit, but frequently with no voltage change

J

Jet line — Line sucked or blown through a conduit by positive or negative pressure so a rope or tape can be pulled through a conduit

Jogging (inching) — Momentarily operating; moving driven machine a small distance; the quickly repeated closure of a circuit to start a motor from rest for the purpose of accomplishing small movements

K

Knockout cutter — Used to cut holes, slots, and cuts in electrical boxes and studs

L

Ladder diagram (line diagram) — Schematic consisting of symbols and lines that indicate power source and how current flows through various parts of a control circuit

Lightning arrestor — Device connected to the supply side of a system, designed to absorb transient surges

Logic — A system that contains digital switching functions, circuits, or devices

Low voltage protection — Magnetic control only; nonautomatic restarting; three-wire control; power failure disconnects service; power restored by manual restart

Low voltage release — Manual and magnetic control; automatic restarting; two-wire control; power failure disconnects service; when power is restored the controller automatically restarts motor

Lumens — A unit of light emitted from a point light source of one candle through a unit solid angle

M

Magnetic contactor — Contactor operated electromechanically

Mechanical interlocking — Means of locking out contactors through the use of mechanical devices such as cams or blocks

Motor control center — Large panel used in industrial applications to centrally locate motor starters, motor branch circuit short circuit and ground fault protective devices, and motor branch circuit disconnecting means

Motor driven timing relay — Relay whose timed contacts are operated through the action of a variable speed, extremely small motor

Multispeed starter — Starter designed to start motor at a reduced speed and build to full speed in preset steps

N

Networking — Tying in of multiple PCs to communicate with each other in the performance of a process

O

One-line diagram — Schematic consisting of single-phase and three-phase power lines; indicates power distribution and fuse and interrupter coordination

Output — A signal coming from the controller to field devices; can be discrete, numeric, or analog

Overload relay — Device for protecting motor from overload current or voltage

P

Phosphor — Coating inside a fluorescent bulb that determines the color of light

Photocell — Light activated switch

Photometer — Instrument used to determine lumens

Pilot device — Directs operation of another device; alters the electrical circuit

Pipe chase — Usually a vertical space between two floors, dedicated for the running of pipes and conduits between floors

PK — Pink lamp

Pneumatic timing relay — Relay whose timed contacts are operated through the action of an air bellows and needle valve

Powder actuated device — Uses charges that shoot studs and tie downs into concrete, metal, and wood

Power factor — Ratio of active power to apparent power

Power fish-tape system — Vacuum or air pressure system for installing a pull cord in a raceway in order to pull in the heavy pull rope for heavy and long pulls

Programmable controller (PC; PLC) — A solid state control system that contains a user programmable memory for the storage of instructions to perform specific functions in an operation

Programmer — A device designed to allow inserting, monitoring, and editing a user program in the PC

PT — Potential transformer

Pull rope — Strong rope of nylon or other substance used to pull heavy conductors into raceways

Pulling equipment — Used to pull multiple and large conductors through a conduit; may be manual or electrically operated

Pulling lube — Wax-based product that allows the conductors to pass through the conduit causing less friction

Pulling sleeve — Attaches around the end of conductors so they may be pulled through a conduit

Push button — Switch, manually operable plunger, button, or actuating device

Push-button interlocking — Means of interlocking reversing starters through the use of two-circuit push buttons with normally open and normally closed contacts

Push-to-test pilot light — Used to indicate "on" and "off" status of a motor and to verify condition by means of indicating a burned out lamp

R

Raceway — An enclosed channel designed expressly for holding wires, cables, or busbars, with additional functions as permitted in the *National Electrical Code*

Racing — Condition that occurs when both forward and reversing push buttons are operated simultaneously; coil "race" to close

Relay — Electromechanical device operated by a coil; uses contacts to make or break circuits

Remote control — Device that controls electrical apparatus from some distance

Reversing starter — Starter consisting of two identical contactors and one overload relay assembly; used in reversal of polyphase motors

S

Selector switch — Manually operated multiposition switch

Service — Where power is metered or is first attached to the structure

Service drop — Power conductors coming into building from power company

Service panel — Main control panel where voltage and current are distributed to different locations

Shading coil — Single turn of conducting material mounted on the magnetic assembly face to produce out-of-phase magnetic force

Single phasing — Loss of one phase of a three-phase system

Solid state timing relay — Relay whose timed contacts are operated by an electronic timer (microchip)

Specifications — A detailed set of written instructions that explains the drawing

Starter — Device used to make and break electrical power circuit; control device with electric contactor and overload protection; designed to protect motor from voltage inrush during starting

Strippers — Used to remove insulation from conductors

Switch board — Large single panel, frame, or assembly of panels on which are mounted, on the face or back or both, switches, overcurrent, and other protective devices, busses, and usually instruments; generally accessible from the rear as well as the front and intended to be installed in a cabinet

Symbol — An arbitrary sign that has been standardized and is used to represent an object, quantity, or method

T

Thermal overload (heater) — Device used to sense current draw in a circuit and open a control circuit when its rating is exceeded

Threading tools — Used to thread pipe so electrical fittings may be attached to conduit

Three-wire control — Uses momentary contact; start/stop stations and a memory circuit interlock connected in parallel with the start button to maintain the circuit

Time clock — An electromechanical or electronic switch designed to control electrical circuits and equipment based on preset times of day

Timer — Pilot device that delays closing or opening of a circuit for a specific time; may be motor driven, solenoid-actuated, or electric

Torque — Force that produces a rotating or twisting action

Transformer vault — Area in which transformers are installed for safety protection, usually constructed with concrete and fire-retardant doors

Trencher — Machine used to dig trenches

Trim out — Final stage in a wiring project; involves devices and plates, connecting and securing equipment, hanging fixtures, and testing the system

Troubleshooting — The systematic diagnosis of a malfunction

Two-wire control — Any type of switch having definite "on" and "off" positions that is used to control a magnetic starter or contactor

U

Under voltage relay — Relay whose coils are connected between the line terminals of a motor branch circuit; opens a set of N/O contacts if one or more phases is lost

V

Voltage drop — A reduction in available voltage at the end of a circuit

Voltage rating — Maximum and minimum voltage at which a device is designed to operate

W

W — White lamp

Winch — Manual or motor-powered mechanical device used to pull conductors into a raceway

Wire dispenser — Movable rack used to hold one or more reels of wire so that wire can be easily pulled off reel and fed into raceway

Wire-pulling compound — Compound of soap and other substances used to lubricate conductors being pulled or pushed into a raceway

Wiring diagram — Consists of symbols and lines that indicate all connections and placement of all component parts in a device or circuit, including the power circuit wiring

WW — Warm white lamp

Wye — Three-phase circuit in which the windings are connected to form the shape of a "Y" (120 electrical degrees apart)

Blueprint Reading and Load Calculations
Unit 1

Objective Sheet

Unit Objective

After completing this unit, the student should be able the identify blueprint symbols and compute load calculations and voltage drop. The student should demonstrate these competencies by completing the assignment sheets, and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to blueprint reading and load calculations with their correct definitions.
2. Identify mechanical symbols.
3. Identify plumbing symbols.
4. Identify structural symbols.
5. Identify architectural symbols.
6. Identify electrical symbols.
7. Identify panel, circuit, and other electrical symbols.
8. Match types of blueprint lines with their pictures and descriptions.
9. List typical electrical specifications.
10. Complete statements concerning minimum requirements for electrical devices.
11. Determine motor-circuit wire sizes by using the *NEC*.
12. Select true statements concerning load calculations.
13. Select true statements concerning voltage drop.
14. Match types of blueprints with their correct descriptions.
15. Construct an electrical blueprint. (Assignment Sheet 1)

Objective Sheet

16. Perform load calculations and determine overcurrent protection and conductor size. (Assignment Sheet 2)
17. Compute lighting loads. (Assignment Sheet 3)
18. Derate neutral loads. (Assignment Sheet 4)
19. Determine maximum numbers of conductors in conduit. (Assignment Sheet 5)
20. Determine wire sizes to prevent voltage drop. (Assignment Sheet 6)

Blueprint Reading and Load Calculations
Unit 1

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.

2. Review Teaching Suggestions section that follows. Plan for classroom activities.

3. Plan for students with special needs.

4. Make transparencies from the transparency masters included with this unit. These appear in the teacher edition only and are designed to be used with the following objectives:

   TM 1—Alphabet of Lines (Objective 8)
   TM 2—Electrical Floor Plan (Objective 14)
   TM 3—Floor Plan (Objective 14)
   TM 4—Foundation Plan (Objective 14)
   TM 5—Elevations (Objective 14)
   TM 6—Plot Plan (Objective 14)
   TM 7—Details (Objective 14)

5. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.

6. Develop teaching plan. Adjust for different learning styles.

7. Make copies of Unit Evaluation Form.

Delivery and Application

8. Provide students with unit of instruction.

9. Discuss unit and specific objectives.

10. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.

11. Discuss the assignment sheets. Review criteria for evaluation of these activities.

Suggested Activities

Evaluation

12. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

13. Make copies of the written test. Add or modify test items as needed.

14. Give written test.

15. Record assignment sheet ratings and written test scores on the Unit Evaluation Form. Add any additional assignments or supplemental activities that should be part of the unit evaluation.

16. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Take students on a field trip to a construction site. Arrange for students to observe both the blueprints and the actual work on site. Skill areas: **listening** and **learning to learn**.

2. Have a representative from a local engineering firm talk to the class about the importance of knowing how to read various types of blueprints. Skill area: **listening**.

3. Invite a local inspector to class to discuss pertinent codes and requirements. Conduct a question and answer period to enhance the discussion. Skill areas: **listening** and **oral communication**.

4. Show students examples of various types of blueprints. Have the class identify the symbols used. Skill area: **oral communication**.

Resources Used in Developing This Unit

1. Kaltwasser, Stan and Gary Flowers. *Commercial and Industrial Wiring.* Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1988.

2. Mullin, Ray C. and Robert L. Smith. *Electrical Wiring—Commercial.* Albany, NY: Delmar Publishers, Inc., 1990.

Suggested Activities

3. *National Electrical Code 1993.* Quincy, MA: National Fire Protection Association, 1992.

4. Teague, Cash and Garner Pewewardy. *Industrial Electricity: In-Plant Distribution.* Stillwater, OK: Oklahoma Curriculum and Instructional Materials Center, 1984.

Suggested Supplemental Resources

1. Croft, Terrell and Wilford I. Summers. *American Electrician's Handbook*, 11th Ed. New York: McGraw-Hill Book Company, 1987.

2. Earley, Mark W., John M. Caloggero and Richard H. Murray. *NEC Handbook 1993.* Quincy, MA: National Fire Protection Association, 1992.

3. O'Riley, Ronald P. *Illustrated Changes in the 1993 National Electrical Code.* Albany, NY: Delmar Publishers, Inc., 1993.

Instructions for Evaluating Student Performance

Assignment Sheets—Be sure the student understands the criteria on which the evaluation is based. Assign a point value to each criterion and convert the total points to a percentage for grading.

Job Sheets—Be sure the student understands the criteria on which the evaluation is based. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher edition or student manual. Then observe the student performing the procedure. Rate both process and product.

> Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.
>
> Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. Complete the rating by assigning a point value to each criterion and by converting the point total to a percentage for grading. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Suggested Activities

Sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) which best fits your program needs.

Option A

4 - Skilled—Can perform job with no additional training.
3 - Moderately skilled—Has performed job during training program; limited additional training may be required.
2 - Limited skill—Has performed job during training program; additional training is required to develop skill.
1 - Unskilled—Is familiar with process, but is unable to perform job.

Option B

Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

Blueprint Reading and Load Calculations
Unit 1

Answers to Assignment Sheets

Assignment Sheet 1 — Answers may vary according to individual students. Look for basic understanding of concepts and correct use of symbols.

Assignment Sheet 2

A. 125 Amp Fuse, #12 AWG THHN
B. 150 Amp Fuse, #1 AWG THHN
C. 70 Amp Fuse, #6 AWG THWN
D. 350 Amp Fuse, 500 kcmil THW
E. 30 Amp Fuse, #10 AWG TW
F. 30 Amp Fuse, #10 AWG TW
G. 45 Amp Fuse, #8 AWG THHN
H. 40 Amp Fuse, #8 AWG THHN
I. 50 Amp Fuse, #8 AWG THHN
J. 200 Amp Fuse, 3/0 THHN
K. 80 Amp Fuse, #4 AWG THW
L. 80 Amp Fuse, #4 AWG THW (Maximum)
40 Amp Fuse, #10 AWG THW
M. 30 Amp Fuse, #10 AWG THHN
N. 10 Amp Fuse, #14 AWG THWN
O. 10 Amp Fuse, #14 AWG THWN
P. 50 Amp Fuse, #8 AWG THHN
Q. 1600 Amp Fuse, 4-600 kcmil, paralleled per phase (maximum)
1000 Amp Fuse, 3-35 kcmil, paralleled per phase
R. 1600 Amp Fuse Ground Fault Protected,
4-600 kcmil, paralleled per phase

Assignment Sheet 3

A. 168.75 amps
B. 5.31 amps
C. 21.5 amps
D. 26.82 amps
E. 11.25 amps

Answers to Assignment Sheets

Assignment Sheet 4

A. 495 Amps; 506.5 Amps
B. 143 Amps; 428 Amps
C. 275 Amps; 302.5 Amps
D. 79 Amps; 79 Amps

Assignment Sheet 5

A. 4
B. 10
C. 142
D. 9
E. 18

Assignment Sheet 6

A. #4 AWG
B. #8 AWG
C. #4 AWG
D. #1/0

Blueprint Reading and Load Calculations
Unit 1

Answers to Written Test

1. a. 2 e. 5
   b. 8 f. 6
   c. 3 g. 7
   d. 1 h. 4

2. a. Anchor
   b. Register or grille
   c. Louver opening
   d. Duct section notation
   e. Rainproof ventilator
   f. Duct section, exhaust return
   g. Standard ventilator
   h. Fan flexible connection
   i. Duct connection below joist
   j. Duct section, supply

3. a. Shower stall
   b. Water closet (low tank)
   c. Plain kitchen sink
   d. Meter
   e. Drain
   f. Water heater
   g. Drinking fountain (wall type)
   h. Corner bath
   i. Laundry tray
   j. Corner lavatory
   k. Hot water tank
   l. Hose rack
   m. Vacuum outlet
   n. Cleanout
   o. Roof sump
   p. Gas outlet
   q. Drinking fountain (pedestal type)
   r. Urinal (stall type)
   s. Wash sink
   t. Shower head
   u. Garage drain

Answers to Written Test

4. a. Plan view of single window in frame wall
   b. Plan view of interior pocket door
   c. Plan view of interior hinged door
   d. Plan view of exterior door in wood frame wall
   e. Plan view of multiple windows in frame wall
   f. Plan view of double hung window in frame wall
   g. Plan view of exterior sliding door in wood frame wall
   h. Plan view of folding door

5. a. Wood
   b. Stone
   c. Glass
   d. Sheet metal flashing
   e. Insulation
   f. Brick
   g. Concrete block
   h. Plaster

6. a. Three way switch
   b. Double pole switch
   c. Low voltage wire
   d. Horn
   e. Fused switch
   f. Fluorescent light
   g. Single pole switch
   h. Switch with pilot light
   i. Bell
   j. Push button
   k. Square recessed light
   l. Chime
   m. Buzzer
   n. Switch for low voltage system
   o. Circuit breaker
   p. Low voltage master switch
   q. Duplex receptacle outlet
   r. Round recessed light
   s. Lampholder
   t. Clock outlet
   u. Automatic door switch
   v. Weatherproof switch
   w. Electric door opener
   x. Switch leg indicator
   y. Relay equipped lighting outlet
   z. Split wired receptacle outlet
   aa. Weatherproof duplex outlet
   bb. Special circuit

Answers to Written Test

cc. Rectangular recessed light
dd. Fan outlet
ee. Lighting outlet
ff. Four way switch
gg. Single receptacle outlet
hh. Isolated ground receptacle
ii. Junction box
jj. Lampholder with pull switch
kk. Television outlet
ll. Outside telephone
mm. Baseboard heat

7. a. Lighting panel
b. Generator
c. Controller
d. Power transformer
e. Feeder
f. Switch and fuse
g. Motor
h. Power panel
i. Overcurrent device
j. Instrument

8. a. 3
b. 7
c. 6
d. 8
e. 9
f. 5
g. 4
h. 2
i. 1

9. a. Minimum standards
b. Type of equipment
c. Type of installation
d. Special instructions

10. a. 125
b. 12
c. Square foot
d. Motors, appliances

11. a. #14
b. #14
c. #14
d. #10
e. #8

12. a, d

13. All are correct.

14. a. 5
b. 4
c. 2
d. 1
e. 6
f. 3

Blueprint Reading and Load Calculations
Unit 1

Written Test

Name ______________________________ Score ______________

1. Match the terms on the right with their correct definitions.

_____a. Set of conventional symbols to depict an object

_____b. A reduction in available voltage at the end of a circuit

_____c. The circuit that extends from the last overcurrent protection device to the outlets

_____d. Copy of the original detailed drawings of a structure

_____e. All circuit conductors between the service equipment of the source of a separately derived system and final branch circuit overcurrent device

_____f. A detailed set of written instructions that explains the drawing

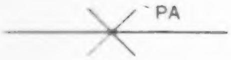
_____g. An arbitrary sign that has been standardized and is used to represent an object, quantity, or method

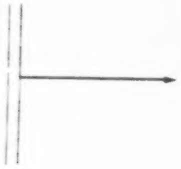
_____h. The ratio of the maximum demand of a system, or part of a system, to the total connected load of a system or the part of the system under consideration

1. Blueprint
2. Blueprint lines
3. Branch circuit
4. Demand factor
5. Feeder circuit
6. Specifications
7. Symbol
8. Voltage drop

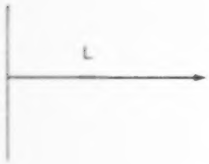
Written Test

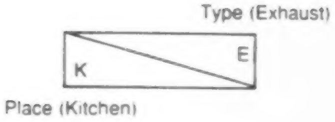
2. Identify the following mechanical symbols.



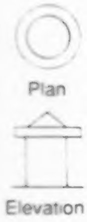


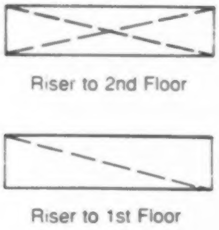
a. ______________________________ b. ______________________________




Type (Exhaust)
E
K
Place (Kitchen)

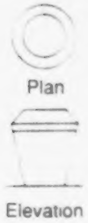
c. ______________________________ d. ______________________________

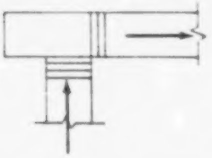

Plan
Elevation


Riser to 2nd Floor
Riser to 1st Floor

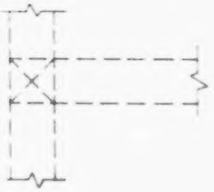
e. ______________________________ f. ______________________________

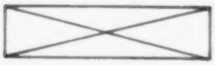
Written Test



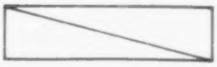


g. ______________________ h. ______________________





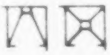
Riser to 1st Floor

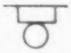


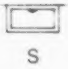
Riser to 2nd Floor

i. ______________________ j. ______________________

3. Identify the following plumbing symbols.

a.  ______________________

b.  ______________________

c. 

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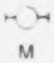
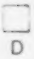
Written Test

d. 

____

e. 

____

f.

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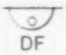
g. 

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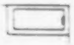
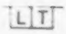
h. 
____

i. 

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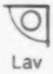
j. 

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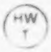
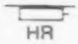
k. 

____

l. 

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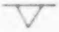
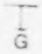
m. 
____

n.

____

Written Test

o. ____________________

p. 

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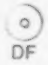
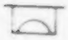
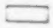
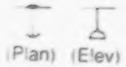
q. 

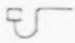
____

r.  ____________________

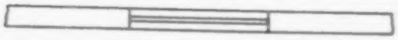
s.  ____________________

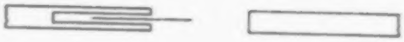
t. 

____

u.  ____________________

4. Identify the following structural symbols





a. ____________________ b. ____________________

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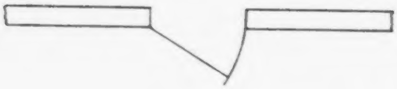
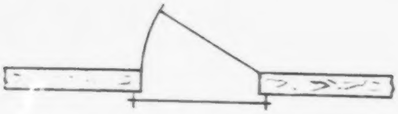
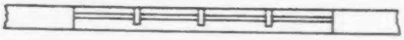


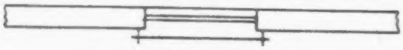
c. ______________________________



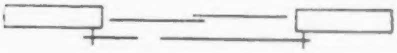
d. ______________________________



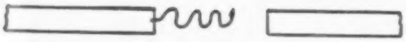
e. ______________________________



f. ______________________________



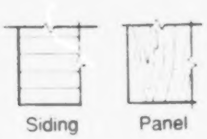
g. ______________________________



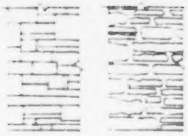
h. ______________________________

Written Test

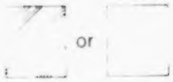
5. Identify the following architectural symbols.



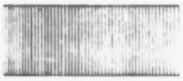
a. ____________________



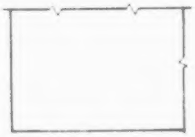
b. ____________________



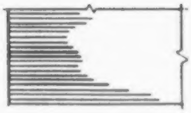
c. ____________________



d. ____________________



e. ____________________



f. ____________________

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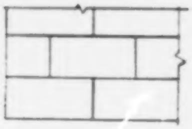
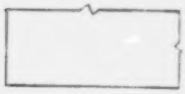




g. ____________________ h. ____________________

6. Identify the electrical symbols below.

a. S_3 ____________________

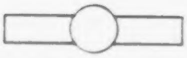
b. S_2 ____________________

c. —— – – —— – – —— ____________________

d. $\boxed{H}$ ____________________

e. S_f ____________________

f.

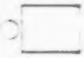


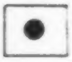
____

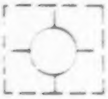
g. $\underline{S}$ ____________________

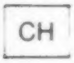
h. S_p ____________________

Written Test

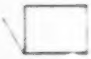
i.  ____________________

j.  ____________________

k.  ____________________

l. 

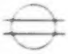
____

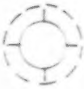
m.  ____________________

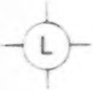
n. S ____________________

o. S_{cb} ____________________

p. M_s ____________________

q.  ____________________

r.  ____________________

s. 

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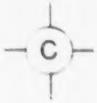
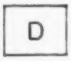
Written Test

t. 

____

u. S_D ______________________________

v. S_{wp} ______________________________

w. 

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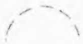
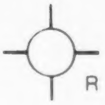
x.  ______________________________

y. 

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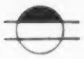
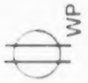
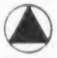
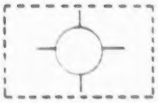
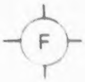
z.  ______________________________

aa. 

____

bb.  ______________________________

cc.  ______________________________

dd. 

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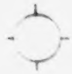
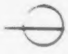
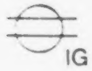
Written Test

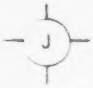
ee.  ______________________________

ff. S_4 ______________________________

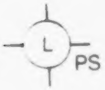
gg.  ______________________________

hh. 

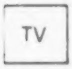
____

ii. 

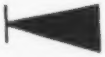
____

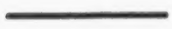
jj. 

____

kk. 

____

ll.  ______________________________

mm.  ______________________________

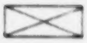
7. Identify the panel, circuit, and other electrical symbols below.

a. ______________________________

b.

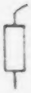
____

Written Test

c.  ________________________________

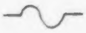
d. ________________________________

e. ________________________________

f.  ________________________________

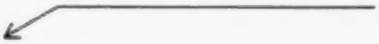
g. ________________________________

h. ________________________________

i.  ________________________________

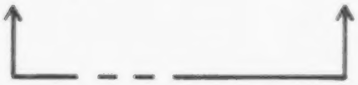
j. ________________________________

8. Match the names of types of blueprint lines on the right with their pictures and descriptions.

______a.	 Used to connect a note or dimension to a part of the building	1. Object lines 2. Center lines 3. Leaders
______b.	- Short dashes used to show lines that are not visible from that view	4. Extension lines 5. Section lines

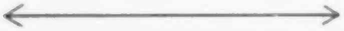
Written Test

______ c.



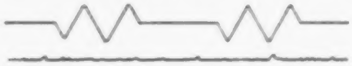
Heavy lines consisting of a series of one long and two short dashes with arrows at each end pointing away from the area that is cut away for the purpose of sectioning

______ d.



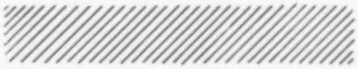
Thin unbroken lines upon which building dimensions are placed

______ e.



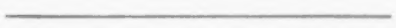
Used when an area cannot or should not be drawn in its entirety

______ f.



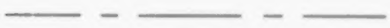
A series of lines of various shapes or symbols used to depict an area that is a cross section of the whole object and also depict the type of material to be used in construction

______ g.



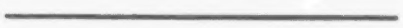
Extend, but do not touch, the object lines and permit dimension lines to be drawn between them

______ h.



A series of short and long dashes used to designate the centers of doors, windows, and circles and to provide reference points for dimensioning

______ i.



Show the main outline of the building including exterior walls, interior partitions, porches, patios, driveways, and interior walls; should be the outstanding lines on a drawing

6. Cutting-plane lines
7. Hidden lines
8. Dimension lines
9. Break lines

Written Test

9. List four typical electrical specifications.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

10. Complete the following statements concerning minimum requirements for electrical devices.

    a. Rooftop heating, air conditioning, and refrigeration equipment must have a ______________ GFCI volt receptacle within 25 feet of equipment.

    b. Show windows must have one receptacle for each ______________ linear feet.

    c. A unit of not less than that specified in *NEC* Table 220-3(b) for occupancies listed therein shall constitute the minimum lighting load for each ______________ of floor area.

    d. Disconnects are required by code for ______________ and ______________ and each service, feeder, or branch circuit at the point where it originates and shall be legibly marked.

11. Determine the following motor-circuit wire sizes by using the *NEC*.

    a. 1hp 240 volts 1ϕ ______________________________

    b. 2hp 240 volts 3ϕ ______________________________

    c. 3hp 240 volts 3ϕ ______________________________

    d. 7.5 hp 240 volts 3ϕ ______________________________

    e. 15 hp 240 volts 3ϕ ______________________________

84

Written Test

12. Select true statements concerning load calculations by placing an "X" in the blank preceding each true statement.

______a. Feeder size is determined by branch circuit loads to be supplied.

______b. For 3-wire DC or single phase AC, 4-wire, 3 phase and 5-wire, 2 phase systems, a further demand factor of 70% shall be permitted for that portion of the unbalanced load in excess of 200 amperes. Ne reduction is permitted on the neutral conductor concerning electric discharge lighting.

______c. Loads for branch circuit calculations are classified in two separate groups: general purpose receptacle loads and motor loads.

______d. Concerning temperature calculations, no conductor shall be used in such a manner that its operating temperature will exceed that designated for the type of insulated conductor involved.

13. Select true statements concerning voltage drop by placing an "X" in the blank preceding each true statement.

______a. If voltage drop is too great, electrical equipment can overheat.

______b. Voltage drop must be considered when feeder and branch-circuit conductors are selected.

______c. The formula for calculating voltage drop is $VD = \frac{2 \times K \times L \times I}{CM}$

______d. The values that may be used when determining voltage drop are:

VD — Voltage drop
K — Resistivity of conductor material
L — One way length of circuit in feet
I — Current in conductor in amperage
CM — Conductor area in circular mils

Written Test

14. Match types of blueprints on the right with their correct descriptions.

_____a. Shows location of building in relationship to layout of land and location of utilities and site lighting

_____b. Clarify placement of exterior lighting and power outlets

_____c. Similar to electrical but shows equipment, wall, and structural support locations

_____d. Shows locations of switches, outlets, lighting, and special equipment

_____e. Clarify specific installation requirements such as j-bolts for site lighting or special equipment mounting devices

_____f. Shows structural support characteristics of building which are pertinent when planning conduit runs

1. Electrical floor plan
2. Floor plan
3. Foundation plan
4. Elevations
5. Plot plan
6. Details

***Permission to duplicate this test is granted.**

Blueprint Reading and Load Calculations
Unit 1

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Assignment Sheet 1—Construct an Electrical Blueprint Rating _____

Comments: ____

____

Assignment Sheet 2—Perform Load Calculations and Determine Overcurrent Protection and Conductor Size Rating _____

Comments: ____

____

Assignment Sheet 3—Compute Lighting Loads Rating _____

Comments: ____

____

Assignment Sheet 4—Derate Neutral Loads Rating _____

Comments: ____

____

Assignment Sheet 5—Determine Maximum Numbers of Conductors in Conduit Rating _____

Comments: ____

____

Assignment Sheet 6—Determine Wire Sizes to Prevent Voltage Drop Rating _____

Comments: ____

____

Written Test Scores

Pretest _____ Posttest _____ Other _____

Other ____

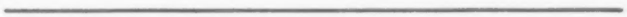
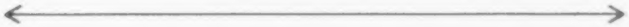
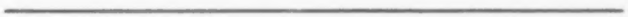
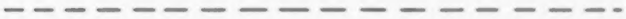
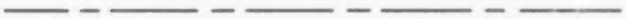
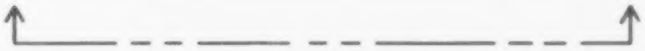
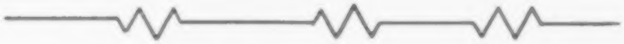
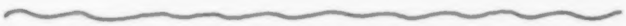
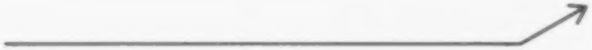
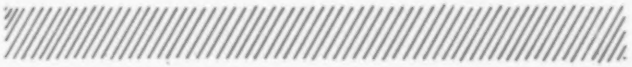
____

Teacher Signature ______________________________ Date __________

Student Signature ______________________________ Date __________

***Permission to duplicate this form is granted.**

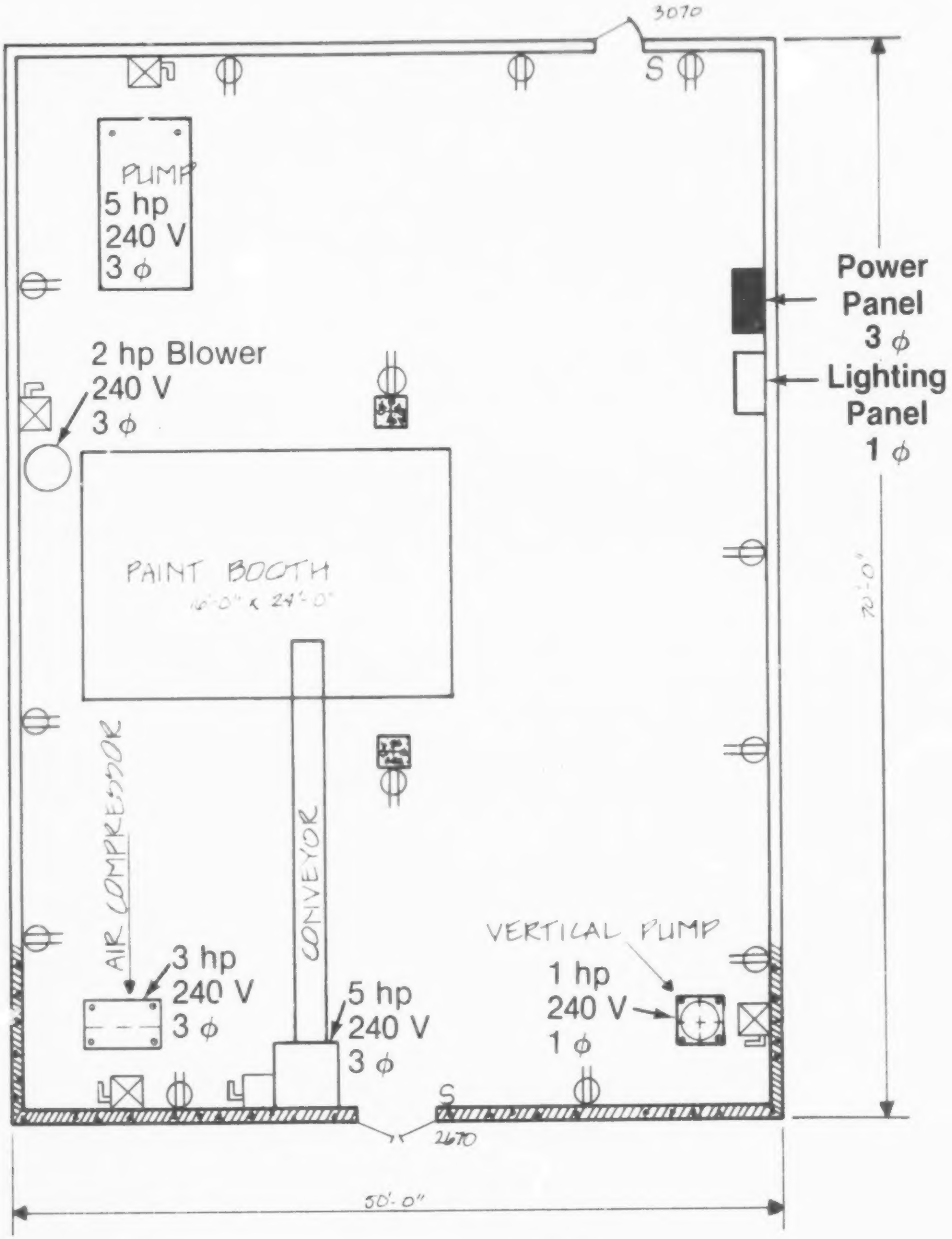
Alphabet of Lines

Object Line	
Dimension Line	
Extension Line	
Hidden Line	
Center Line	
Cutting Plane	
Break Line (Long)	
Break Line (Short)	
Leader	
Section Lines	

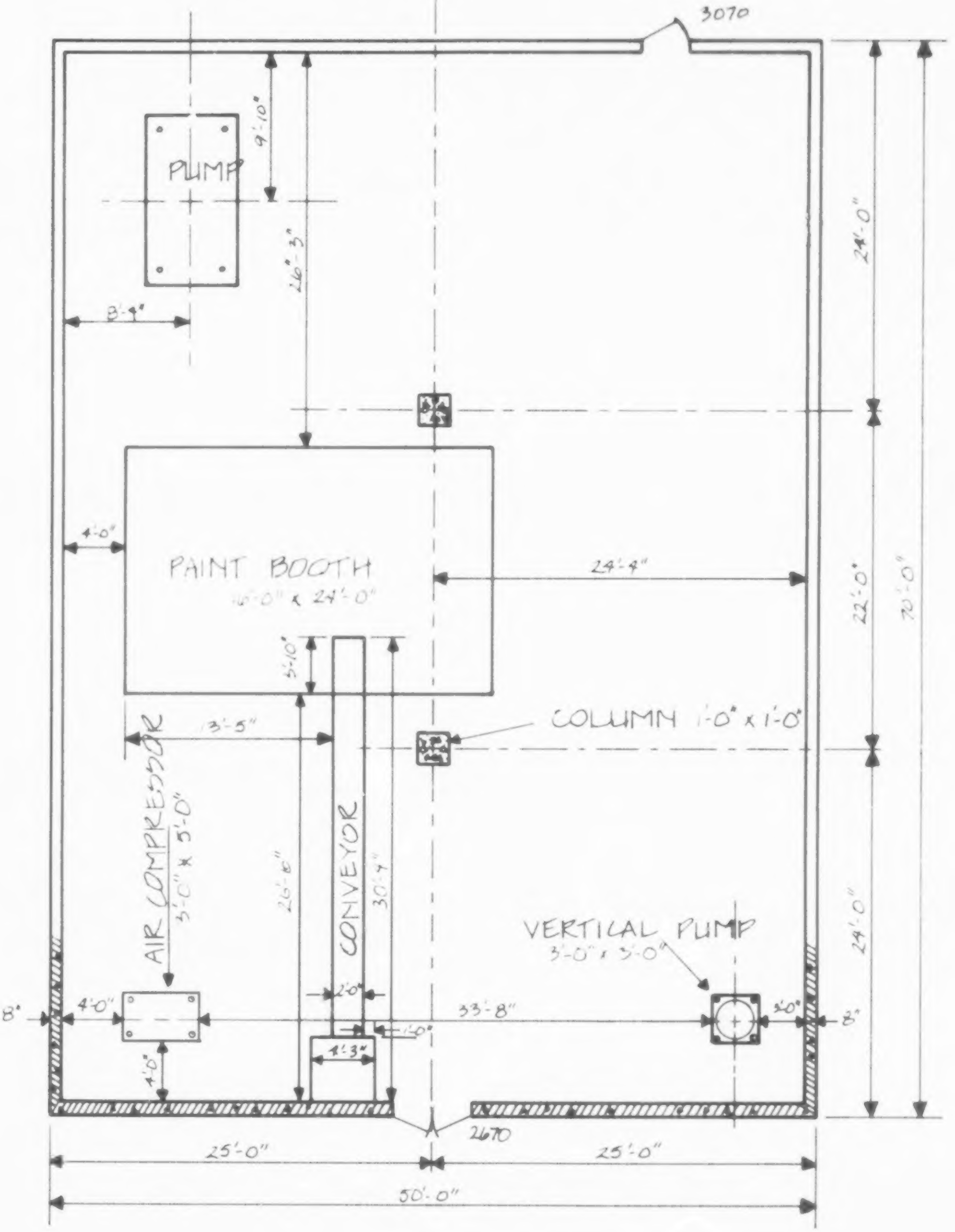
Commercial and Industrial Wiring, Unit 1
Teacher Page 29

TM 1

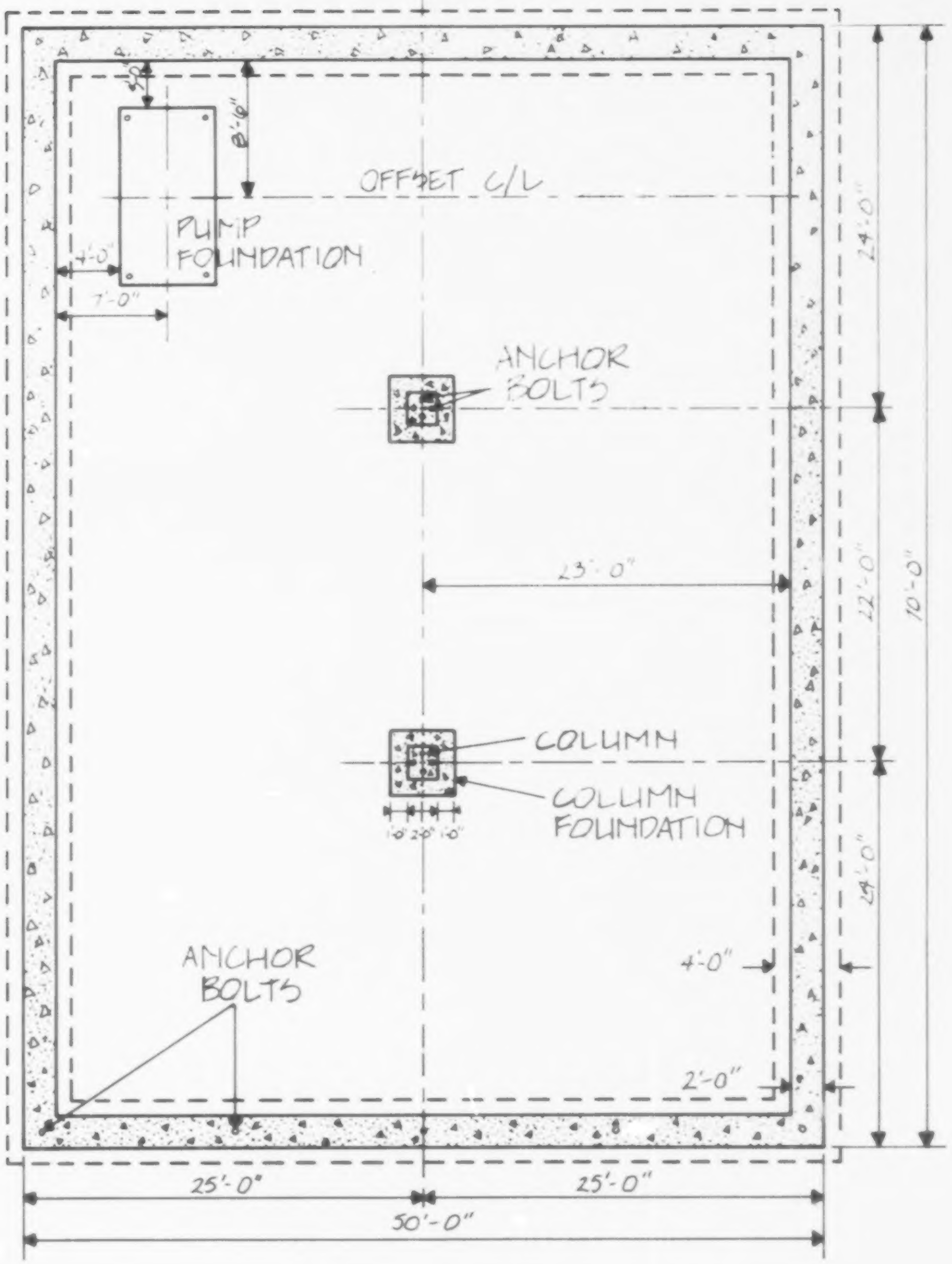
Electrical Floor Plan


3070
S
PUMP
5 hp
240 V
3 ϕ
Power
Panel
3 ϕ
Lighting
Panel
1 ϕ
2 hp Blower
240 V
3 ϕ
PAINT BOOTH
16'-0" x 24'-0"
70'-0"
AIR COMPRESSOR
CONVEYOR
3 hp
240 V
3 ϕ
5 hp
240 V
3 ϕ
VERTICAL PUMP
1 hp
240 V
1 ϕ
S
2670
50'-0"

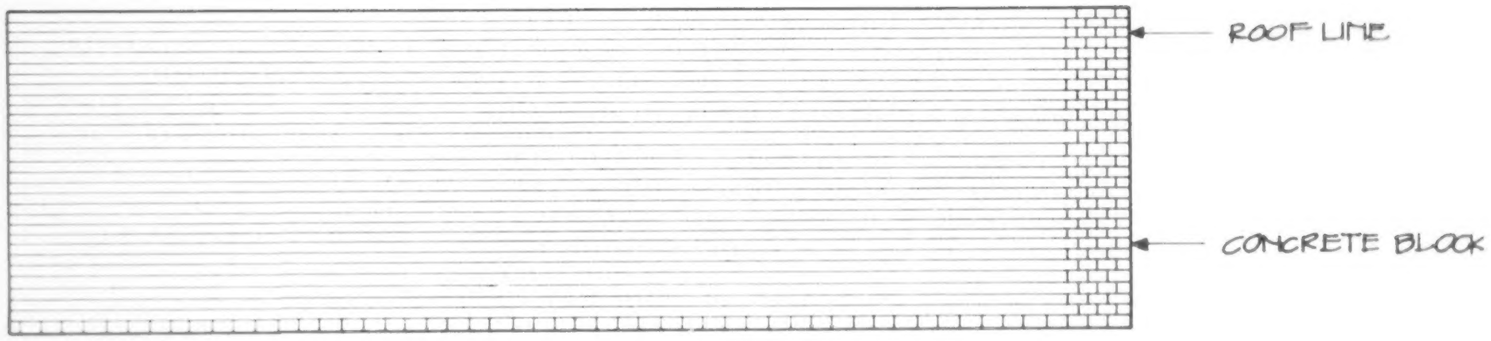
Floor Plan


3070
PUMP
9'-10"
26'-3"
8'-4"
24'-0"
4'-0"
PAINT BOOTH
16'-0" x 24'-0"
24'-4"
22'-0"
70'-0"
3'-10"
13'-5"
COLUMN 1'-0" x 1'-0"
AIR COMPRESSOR
3'-0" x 5'-0"
26'-8"
CONVEYOR
30'-4"
VERTICAL PUMP
3'-0" x 3'-0"
24'-0"
8"
4'-0"
2'-0"
33'-8"
3'-0"
8"
1'-0"
4'-3"
4'-0"
2670
25'-0"
25'-0"
50'-0"

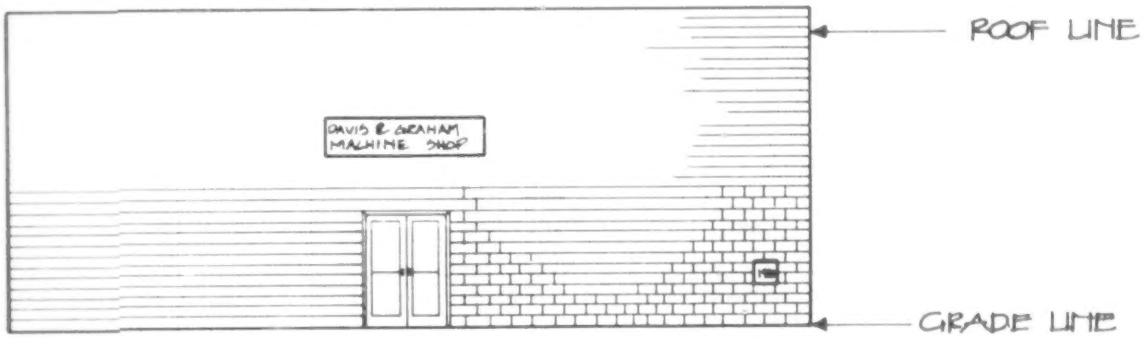
Foundation Plan


5'-0"
8'-6"
OFFSET C/L
PUMP FOUNDATION
4'-0"
7'-0"
ANCHOR BOLTS
24'-0"
23'-0"
22'-0"
70'-0"
COLUMN
COLUMN FOUNDATION
1'-0" 2'-0" 1'-0"
24'-0"
4'-0"
ANCHOR BOLTS
2'-0"
25'-0"
25'-0"
50'-0"

Elevations

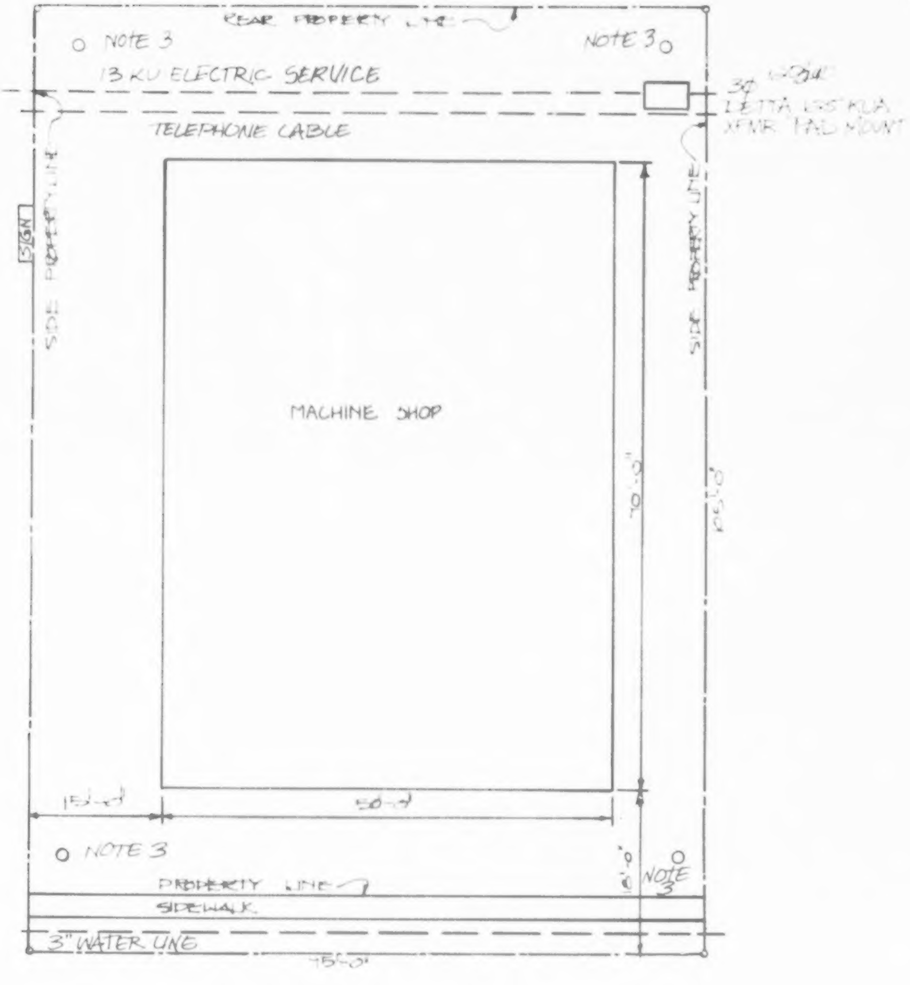

ROOF LINE
CONCRETE BLOCK

WEST ELEVATION


DAVIS & GRAHAM
MACHINE SHOP
ROOF LINE
GRADE LINE

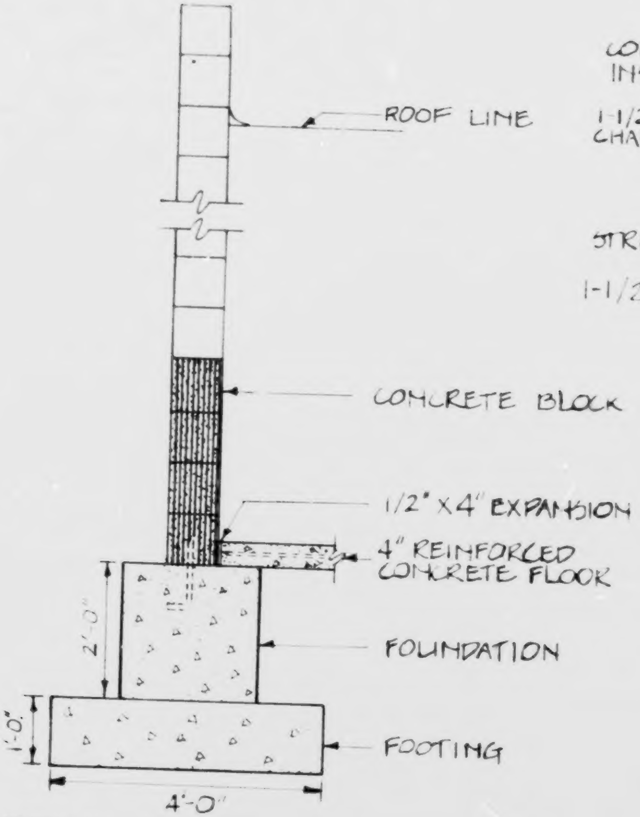
SOUTH ELEVATION

Plot Plan

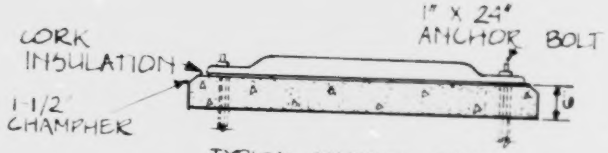

REAR PROPERTY LINE
NOTE 3
NOTE 3
13 KV ELECTRIC SERVICE
3φ
DELTA 125 KVA
XFMR PAD MOUNT
TELEPHONE CABLE
SIGN
SIDE PROPERTY LINE
SIDE PROPERTY LINE
MACHINE SHOP
70'-0"
85'-0"
15'-0"
50'-0"
NOTE 3
NOTE 3
PROPERTY LINE
SIDEWALK
3" WATER LINE
45'-0"

Note 3: 30′ steel pole with one 150W HPS flood.

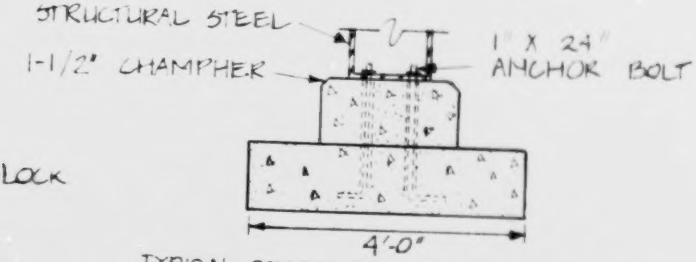
Details


ROOF LINE
CONCRETE BLOCK
1/2" X 4" EXPANSION
4" REINFORCED CONCRETE FLOOR
FOUNDATION
FOOTING
2'-0"
1'-0"
4'-0"

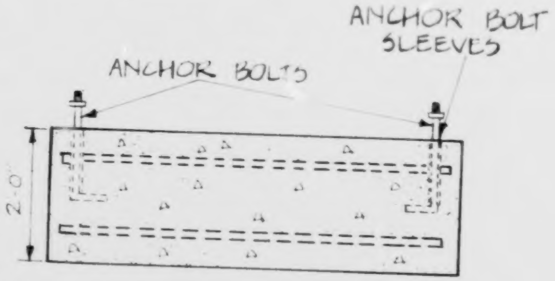
TYPICAL EXTERIOR WALL


CORK INSULATION
1-1/2" CHAMPHER
1" X 24" ANCHOR BOLT
6

TYPICAL MACHINE BASE


STRUCTURAL STEEL
1-1/2" CHAMPHER
1" X 24" ANCHOR BOLT
4'-0"

TYPICAL COLUMN FOUNDATION AND PIER


ANCHOR BOLTS
ANCHOR BOLT SLEEVES
2'-0"

TYPICAL MACHINE FOUNDATION

BEST COPY AVAILABLE

Blueprint Reading and Load Calculations
Unit 1

Information Sheet

1. **Terms and definitions**

   a. **Blueprint** — Copy of the original detailed drawings of a structure

   b. **Blueprint lines** — Set of conventional symbols to depict an object

   c. **Branch circuit** — The circuit that extends from the last overcurrent protection device to the outlets

   d. **Demand factor** — The ratio of the maximum demand of a system, or part of a system, to the total connected load of a system or the part of the system under consideration

   e. **Feeder circuit** — All circuit conductors between the service equipment of the source of a separately derived system and final branch circuit overcurrent device

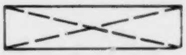
   f. **Specifications** — A detailed set of written instructions that explains the drawing

   g. **Symbol** — An arbitrary sign that has been standardized and is used to represent an object, quantity, or method

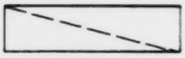
   h. **Voltage drop** — A reduction in available voltage at the end of a circuit

2. **Mechanical symbols**

   a. Duct section, exhaust return

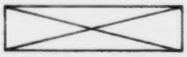


Riser to 2nd Floor

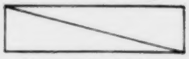


Riser to 1st Floor

   b. Duct section, supply



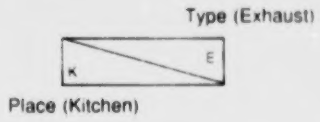
Riser to 1st Floor



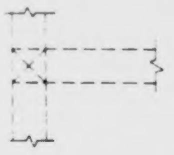
Riser to 2nd Floor

Information Sheet

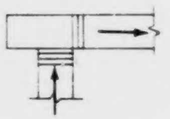
c. Duct section notation


Type (Exhaust)
E
K
Place (Kitchen)

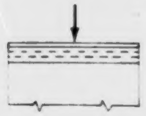
d. Duct connection below joist



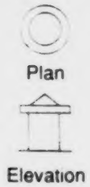
e. Fan flexible connection



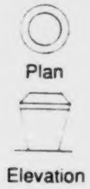
f. Louver 8 screen air intake



g. Rainproof ventilator

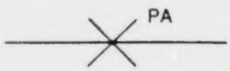

Plan
Elevation

h. Standard ventilator

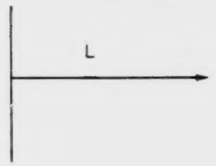

Plan
Elevation

Note: The following symbols depict single line representation.

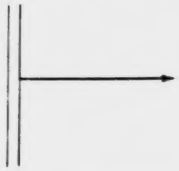
i. Anchor



j. Louver opening



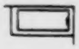
k. Register or grille



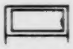
Information Sheet

3. **Plumbing symbols**

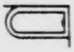
   a. Corner bath —



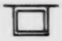
   b. Recessed bath —



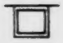
   c. Roll rim bath —



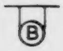
   d. Sitz bath —



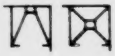
   e. Foot bath —



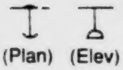
   f. Bidet —



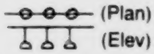
   g. Shower stall —



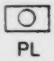
   h. Shower head —



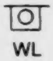
   i. Overhead gang shower —



   j. Pedestal lavatory —

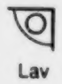


   k. Wall lavatory —

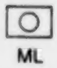


Information Sheet

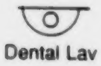
l. Corner lavatory —



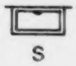
m. Manicure/medical lavatory —



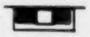
n. Dental lavatory —



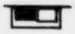
o. Plain kitchen sink —



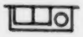
p. Kitchen sink, right and left drain board —



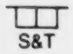
q. Kitchen sink, left hand drain board —



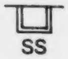
r. Combination sink and dishwasher —



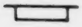
s Combination sink and laundry tray —



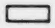
t. Service sink —



u. Wash sink (wall type) —



v. Wash sink —



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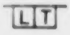
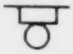
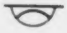
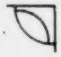
w. Laundry tray — 

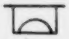
x. Water closet (low tank) — 

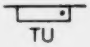
y. Water closet (no tank) —

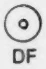
z. Urinal (pedestal type) —

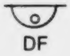
aa. Urinal (wall type) — 

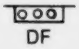
bb. Urinal (corner type) — 

cc. Urinal (stall type) — 

dd. Urinal (trough type) — 

ee. Drinking fountain (pedestal type) — 

ff. Drinking fountain (wall type) — 

gg. Drinking fountain (trough type) — 

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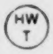
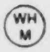
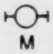
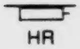
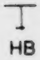
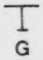
hh. Hot water tank — 

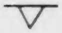
ii. Water heater — 

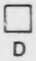
jj. Meter — 

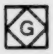
kk. Hose rack — 

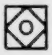
ll. Hose bibb — 

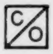
mm. Gas outlet — 

nn. Vacuum outlet — 

oo. Drain — 

pp. Grease separator — 

qq. Oil separator — 

rr. Cleanout — 

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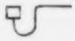
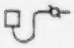
ss. Garage drain —



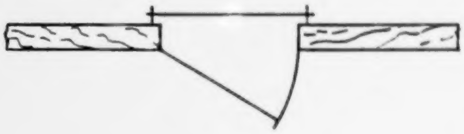
tt. Floor drain with backwater valve —



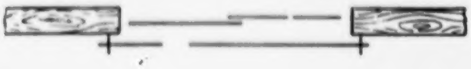
uu. Roof sump —

4. Structural symbols

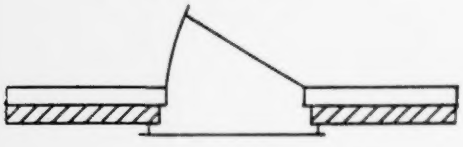
a. Plan view of exterior door in wood frame wall



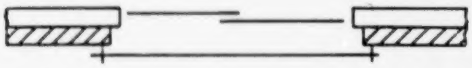
b. Plan view of exterior sliding door in wood frame wall



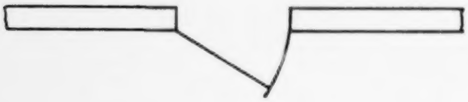
c. Plan view of exterior door in masonry veneer wall



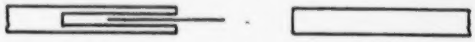
d. Plan view of exterior sliding door in masonry veneer wall



e. Plan view of interior hinged door



f. Plan view of interior pocket door



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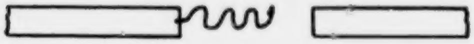
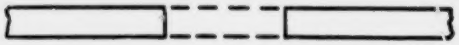
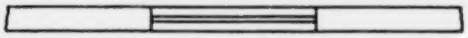
g. Plan view of folding door



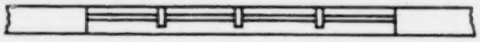
h. Plan view of plastered arch doorway



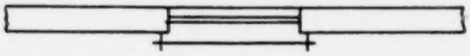
i. Plan view of single window in frame wall



j. Plan view of multiple windows in frame wall

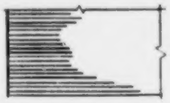
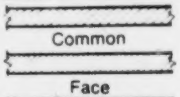
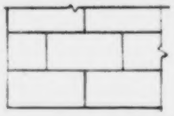
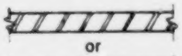
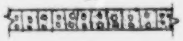
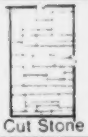
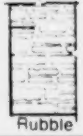
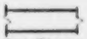
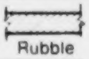
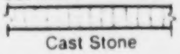
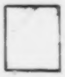
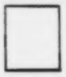
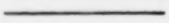
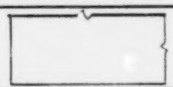
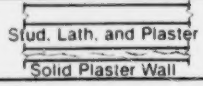
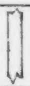
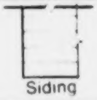
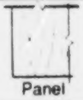
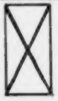
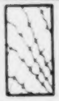
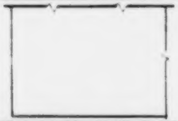
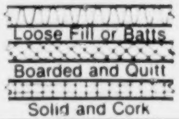
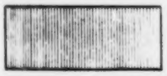
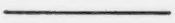
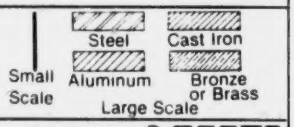
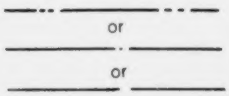
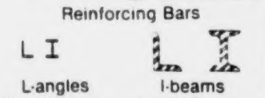


k. Plan view of double hung window in frame wall



Information Sheet

5. Architectural symbols

	ELEVATION	PLAN	SECTION
Brick	 (Common, face, etc.)	 Common Face Firebrick	Same as plan view
Concrete Block		 or 	
Stone	 Cut Stone  Rubble	 Cut Stone  Rubble  Cast Stone (Concrete)	
Glass	 or 		
Plaster		 Stud, Lath, and Plaster Solid Plaster Wall	
Wood	 Siding  Panel	Floor areas are left blank, note indicates kind of wood used	 Rough Member  Trim
Insulation		 Loose Fill or Batts Boarded and Quilt Solid and Cork	Same as plan view
Sheet Metal Flashing		Occasionally indicated by note	
Metals Other than Flashing	Indicated by note or drawn to scale	Same as elevation	 Small Scale Steel Cast Iron Aluminum Bronze or Brass Large Scale
Structural Steel	Indicated by note or drawn to scale		 · or Reinforcing Bars L-angles Small Scale I-beams Large Scale

Information Sheet

6. Electrical symbols

a. Single pole switch — S

b. Three-way switch — S_3

c. Four-way switch — S_4

d. Automatic door switch — S_D

e. Key operated switch — S_K

f. Switch with pilot light — S_p

g. Weatherproof switch — S_{wp}

h. Fused switch — S_f

i. Double pole switch — S_2

j. Switch for low voltage system — $\underline{S}$

k. Circuit breaker — S_{cb}

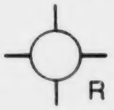
Information Sheet

l. Remote control switch — S_{rc}

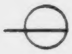
m. Low voltage wire — ——— – – ——— – – ———

n. Low voltage master switch — M_s

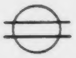
o. Relay equipped lighting outlet —



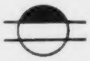
p. Single receptacle outlet —



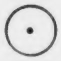
q. Duplex receptacle outlet —



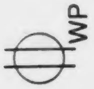
r. Split wired receptacle outlet —



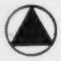
s. Floor receptacle outlet —



t. Weatherproof duplex outlet —

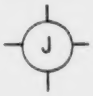


u. Special circuit —



Note: This must be explained in the symbol key.

v. Junction box —



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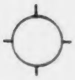
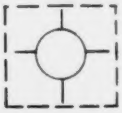
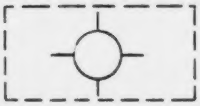
w. Lighting outlet —



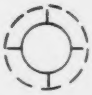
x. Square recessed light (size varies) —



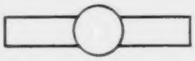
y. Rectangular recessed light (size varies) —



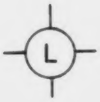
z. Round recessed light (size varies) —



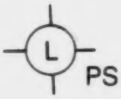
aa. Fluorescent light —



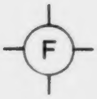
bb. Lampholder —



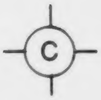
cc. Lampholder with pull switch —



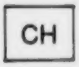
dd. Fan outlet —



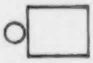
ee. Clock outlet —



ff. Chime —



gg. Bell —



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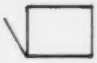
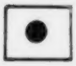
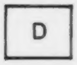
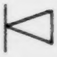
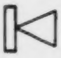
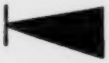
hh. Buzzer — 

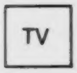
ii. Push button — 

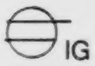
jj. Electric door opener — 

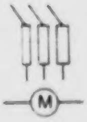
kk. Interconnecting telephone — 

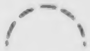
ll. Telephone switchboard — 

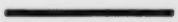
mm. Outside telephone — 

nn. Television outlet — 

oo. Isolated ground receptacle — 

pp. Combination starter — 

qq. Switch leg indicator — 

rr. Baseboard heat — 

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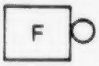
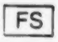
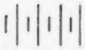
ss. Fire alarm bell — 

tt. Fire alarm station —

uu. Automatic fire alarm device — 

vv. Horn —

ww. Interconnection box —

xx. Battery — 

yy. Auxiliary system circuits — —— – —— – ——

7. Panel, circuit, and other electrical symbols

a. Lighting panel — ■

b. Power panel — ▨

c. Branch circuit, concealed in ceiling or wall — ——

d. Branch circuit, concealed in floor — —·—

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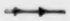
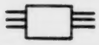
e. Branch circuit, exposed — ----

f. Home run to panelboard — 

Note: The number of circuits is indicated by the number of arrows.

g. Feeder — **—**

Note: Use heavy line and designate by the number corresponding to the listing in the feeder schedule.

h. Under floor duct and junction box (triple system) — 

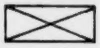
Note: For double or single systems, eliminate one or two lines.

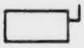
i. Generator — Ⓖ

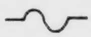
j. Motor — Ⓜ

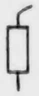
k. Instrument — Ⓘ

l. Power transformer — Ⓣ

m. Controller — 

n. Isolating switch — 

o. Overcurrent device (fuse, breaker, thermal overload) — 

p. Switch and fuse — 

Information Sheet

8. **Types of blueprint lines**

   a. Object lines (――――――――――) show the main outline of the building including exterior walls, interior partitions, porches, patios, driveways, and interior walls; these lines should be the outstanding lines on a drawing.

   b. Dimension lines (←――――――――――→) are thin unbroken lines upon which building dimensions are placed.

   c. Extension lines (――――――――――) extend, but do not touch, the object lines and permit dimension lines to be drawn between them.

   d. Hidden lines (– – – – – – – – – – – – – – –) are short dashes used to show lines that are not visible from that view.

   e. Center lines (――― – ―――――― – ―――) are a series of short and long dashes used to designate the centers of doors, windows, and circles and to provide reference points for dimensioning.

   f. Cutting-plane lines (↑――― – – ―――↑) are heavy lines consisting of a series of one long and two short dashes with arrows at each end pointing away from the area that is cut away for the purpose of sectioning.

   g. Section lines (//////////////////////////////) are a series of lines of various shapes or symbols used to depict an area that is a cross section of the whole object and also depict the type of material to be used in construction.

   h. Break lines (――/\/―――/\/―――) are used when an area cannot or should not be drawn in its entirety.

   i. Leaders (←――――――――――) are used to connect a note or dimension to a part of the building.

9. **Typical electrical specifications**

   a. Minimum standards

      Example: The contractor shall install the complete electrical system according to national and local electrical codes, as per plans and specifications.

   b. Type of equipment

      Example: All switches, duplex receptacles, and other outlets shall be in conduit (EMT will be acceptable). Electrical contractor shall furnish all lighting fixtures as per specifications or approved substitutes.

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c. Type of installation

Example: Electrical service equipment shall be of units specified on plans or shall be approved substitutes or like quality. All work shall be done in coordination with other crafts.

d. Special instructions

Example: Receptacle circuits shall include an equipment grounding conductor of proper size.

10. Minimum requirements for electrical devices

a. Receptacles

Note: Refer to *NEC* Article 210, Part C.

- Rooftop heating, air conditioning, and refrigeration equipment must have a 125 GFCI volt receptacle within 25 feet of equipment.

  Note: Refer to *NEC* Article 210-63.

- Show windows must have one receptacle for each 12 linear feet.

  Note: Refer to *NEC* Article 210-62.

b. Lighting — A unit load of not less than that specified in *NEC* Table 220-3(b) for occupancies listed therein shall constitute the minimum lighting load for each square foot (0.093 sqm) of floor area.

Note: Refer to *NEC* Article 220-3(b).

c. Disconnects — Are required by code for motors and appliances and each service, feeder, or branch circuit at the point where it originates and shall be legibly marked.

Note: Refer to *NEC* Article 110-22.

11. Steps for determining motor-circuit wire sizes

Note: *NEC* Article 430-148 gives normal amperages for single-phase motors, and Article 430-150 gives similar information for three-phase motors.

a. Determine motor size, voltage, and phase from print.

b. Determine full-load amperes from *NEC* Articles 430-148 and 430-150.

Information Sheet

c. Determine circuit ampacity from *NEC* Article 430-22 (continuous-duty motors).

d. Determine wire insulation type, using *NEC* Table 310-13.

e. Determine wire size from *NEC* Table 310-16.

Note: Refer to *NEC* Article 210-19 (FPN 4) and Article 215-2 (FPN 2).

Example: Table 1

Motors	**Full-Load Amps per *NEC* 430-148 *NEC* 430-150**	**Calculated Circuit Ampacity per *NEC* 430-22**	**THW Wire Size *NEC* 310-16**
1 hp 230 Volts 1ϕ	8.0	10.0	#14
2 hp 230 Volts 3ϕ	6.8	8.5	#14
3 hp 230 Volts 3ϕ	9.6	12.0	#14
7.5 hp 230 Volts 3ϕ	22.0	27.5	#10
15 hp 230 Volts 3ϕ	42.0	52.5	#6

12. Load calculations

Note: The *NEC* allows only a specified number of conductors in a raceway. See Tables 3-A and 3-B in Chapter Nine. Also, see Note 8, Table 310-16.

a. Feeder calculations

- Feeder size is determined by branch circuit loads to be supplied.
- No reduction is permitted on the neutral conductor of 3 phase 4-wire wye systems serving electric discharge lighting, data processing, or similar loads. This is referred to as derating neutral.

  Note: Refer to *NEC* Article 220-22.

b. Branch circuit calculations

- Loads are classified in four separate groups:
  - General lighting — Tables 220-3(b) and 220-11
  - General purpose receptacle loads — 220-3(c)(5) and 220-13
  - Special appliance loads — 220-3(c)(5), Exception #1
  - Motor loads — 220-14, 430-22(a), 430-24, and 430-25

Information Sheet

- Concerning temperature calculations, no conductor shall be used in such a manner that its operating temperature will exceed that designated for the type of insulated conductor involved.

  Note: See Tables 310-13 and 310-61 for maximum temperature. Tables 310-16 through 310-19 and 310-69 through 310-84, provide conductor sizes, types, ampacities, ambient temperatures, and number of associated conductors.

13. Voltage drop

Note: Refer to *NEC* Article 215-2 (FPN 2).

a. If voltage drop is too great, electrical equipment can overheat.

b. Voltage drop must be considered when feeder and branch circuit conductors are selected.

c. The formula for calculating voltage drop is $VD = \frac{2 \times K \times L \times I}{CM}$

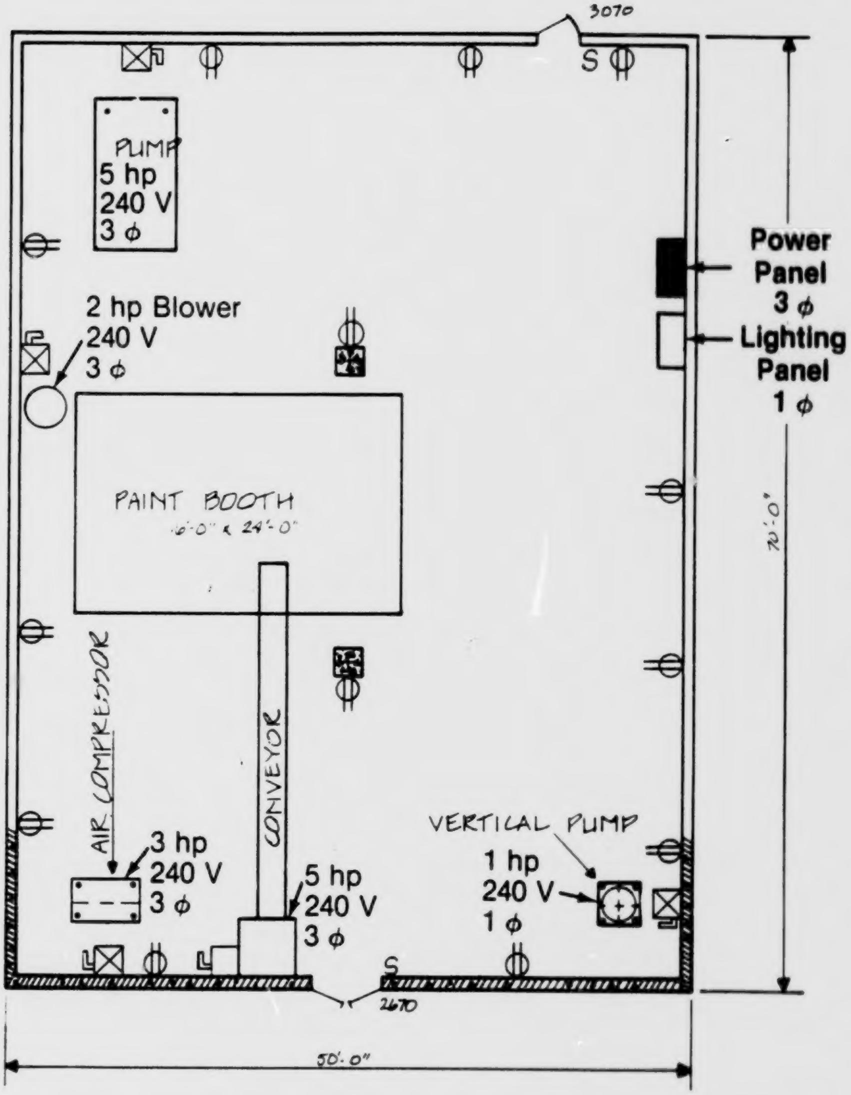
d. The values that may be used when determining voltage drop are:

  - VD — Voltage drop
  - K — Resistor of conductor material (Chapter 9, Table 8, *NEC*)
  - L — One-way length of circuit in feet
  - I — Current in conductor in amperage
  - CM — Conductor area in circular mils (Chapter 9, Table 8, *NEC*)

Information Sheet

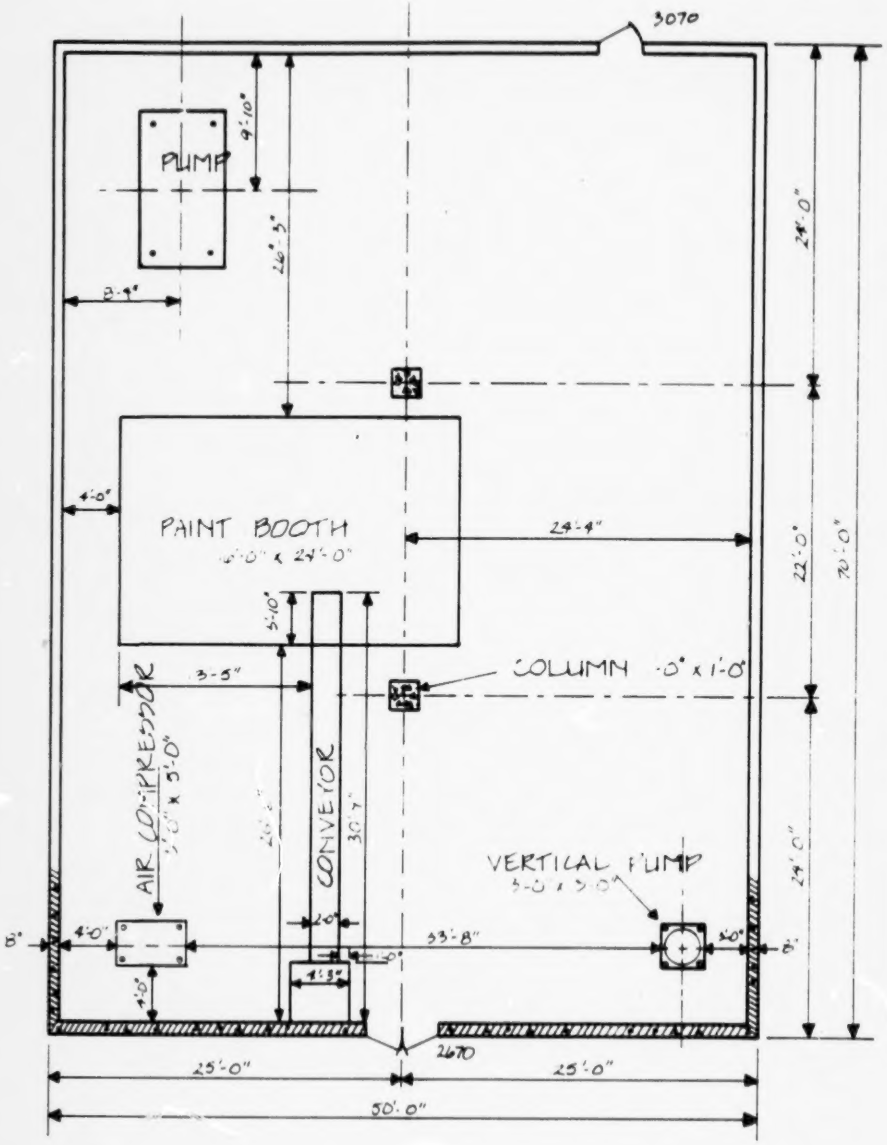
14. Types of blueprints

a. Electrical floor plan — Shows locations of switches, outlets, lighting, and special equipment


3070
S
PUMP
5 hp
240 V
3 φ
Power
Panel
3 φ
Lighting
Panel
1 φ
2 hp Blower
240 V
3 φ
PAINT BOOTH
16'-0" x 24'-0"
70'-0"
AIR COMPRESSOR
CONVEYOR
3 hp
240 V
3 φ
5 hp
240 V
3 φ
VERTICAL PUMP
1 hp
240 V
1 φ
S
2670
50'-0"

Information Sheet

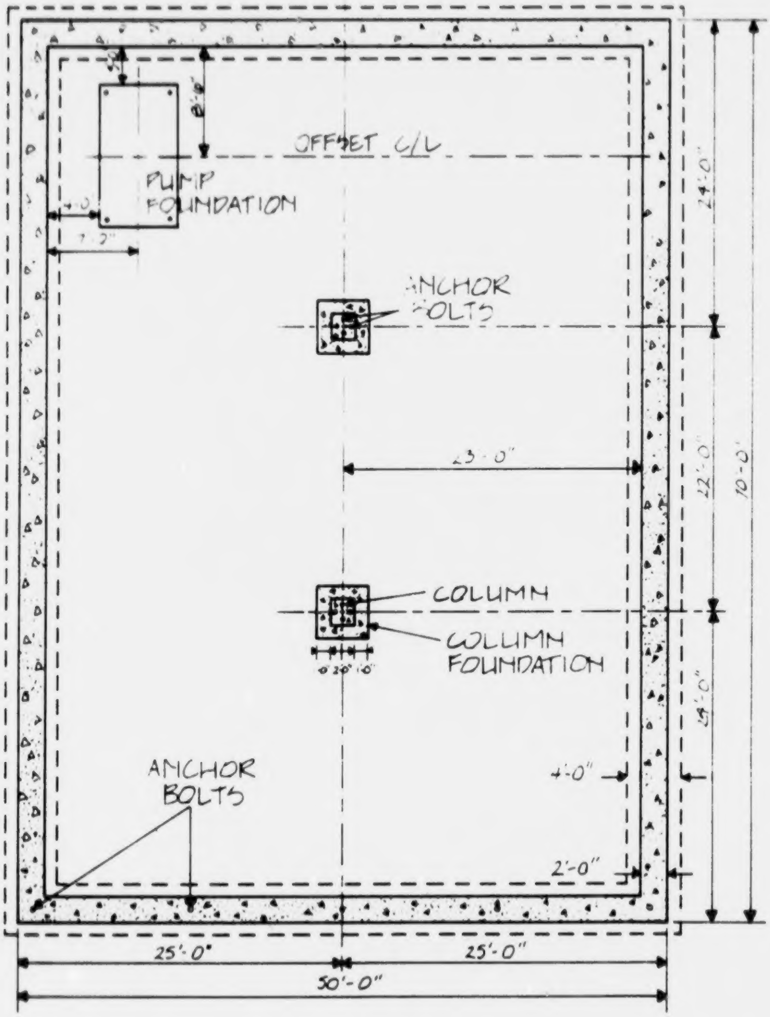
b. Floor plan — Similar to electrical but shows equipment, wall, and structural support locations


3070
PUMP
9'-10"
26'-3"
8'-4"
24'-0"
22'-0"
70'-0"
4'-0"
PAINT BOOTH
6'-0" x 24'-0"
24'-4"
5'-10"
3-5"
COLUMN -0" x 1'-0"
AIR COMPRESSOR
3'-0" x 5'-0"
CONVEYOR
30'-7"
24'-0"
VERTICAL PUMP
3'-0" x 3'-0"
8"
4'-0"
2'-0"
33'-8"
2'-0"
8"
4'-0"
4'-3"
2670
25'-0"
25'-0"
50'-0"

BEST COPY AVAILABLE

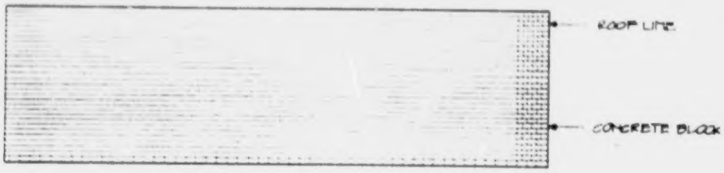
Information Sheet

c. Foundation plan — Shows structural support characteristics of building which are pertinent when planning conduit runs

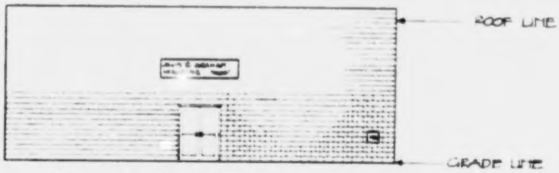

3'-0"
8'-0"
OFFSET C/L
PUMP FOUNDATION
4'-0"
7'-2"
ANCHOR BOLTS
23'-0"
COLUMN
COLUMN FOUNDATION
1'-0" 2'-0" 1'-0"
ANCHOR BOLTS
4'-0"
2'-0"
24'-0"
22'-0"
24'-0"
70'-0"
25'-0"
25'-0"
50'-0"

Information Sheet

d. Elevations — Clarify placement of exterior lighting and power outlets

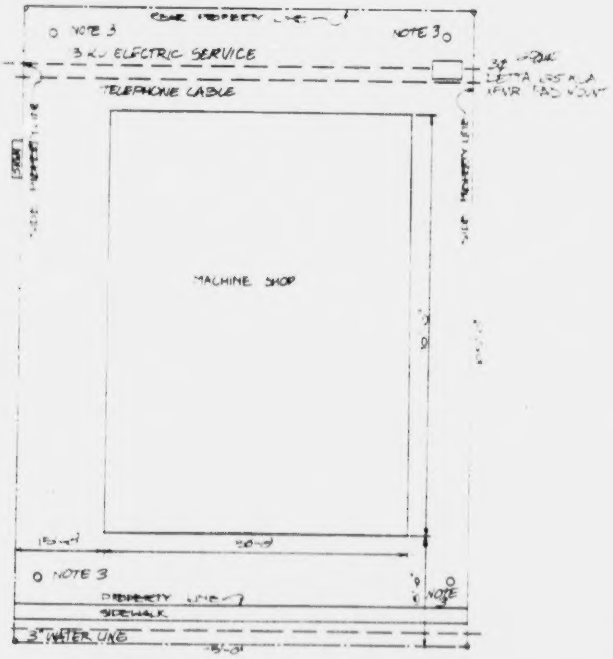

ROOF LINE
CONCRETE BLOCK

WEST ELEVATION


ROOF LINE
GRADE LINE

SOUTH ELEVATION

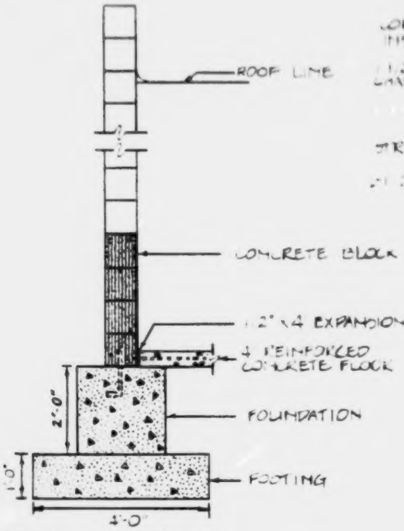
e. Plot plan — Shows location of building in relationship to layout of land and location of utilities and site lighting


REAR PROPERTY LINE
NOTE 3
NOTE 3
3 KV ELECTRIC SERVICE
TELEPHONE CABLE
MACHINE SHOP
NOTE 3
NOTE 3
PROPERTY LINE
SIDEWALK
3" WATER LINE

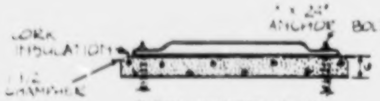
NOTE 3: 30′ steel pole with one 250W HPS flood.

Information Sheet

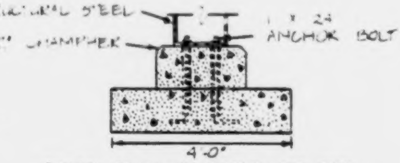
f. Details — Clarify specific installation requirements such as j-bolts for site lighting or special equipment mounting devices


ROOF LINE
CONCRETE BLOCK
1/2" x 4 EXPANSION
4" REINFORCED CONCRETE FLOOR
2'-0"
FOUNDATION
1'-0"
FOOTING
4'-0"

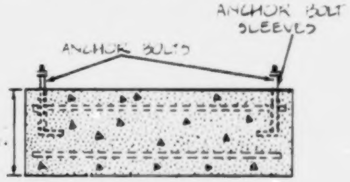
TYPICAL EXTERIOR WALL


x 24" ANCHOR BOLT
CORK INSULATION
1/2 CHAMPHER

TYPICAL MACHINE BASE


STRUCTURAL STEEL
CHAMPHER
x 24 ANCHOR BOLT
4'-0"

TYPICAL COLUMN FOUNDATION AND PIER


ANCHOR BOLT SLEEVES
ANCHOR BOLTS

TYPICAL MACHINE FOUNDATION

Blueprint Reading and Load Calculations
Unit 1

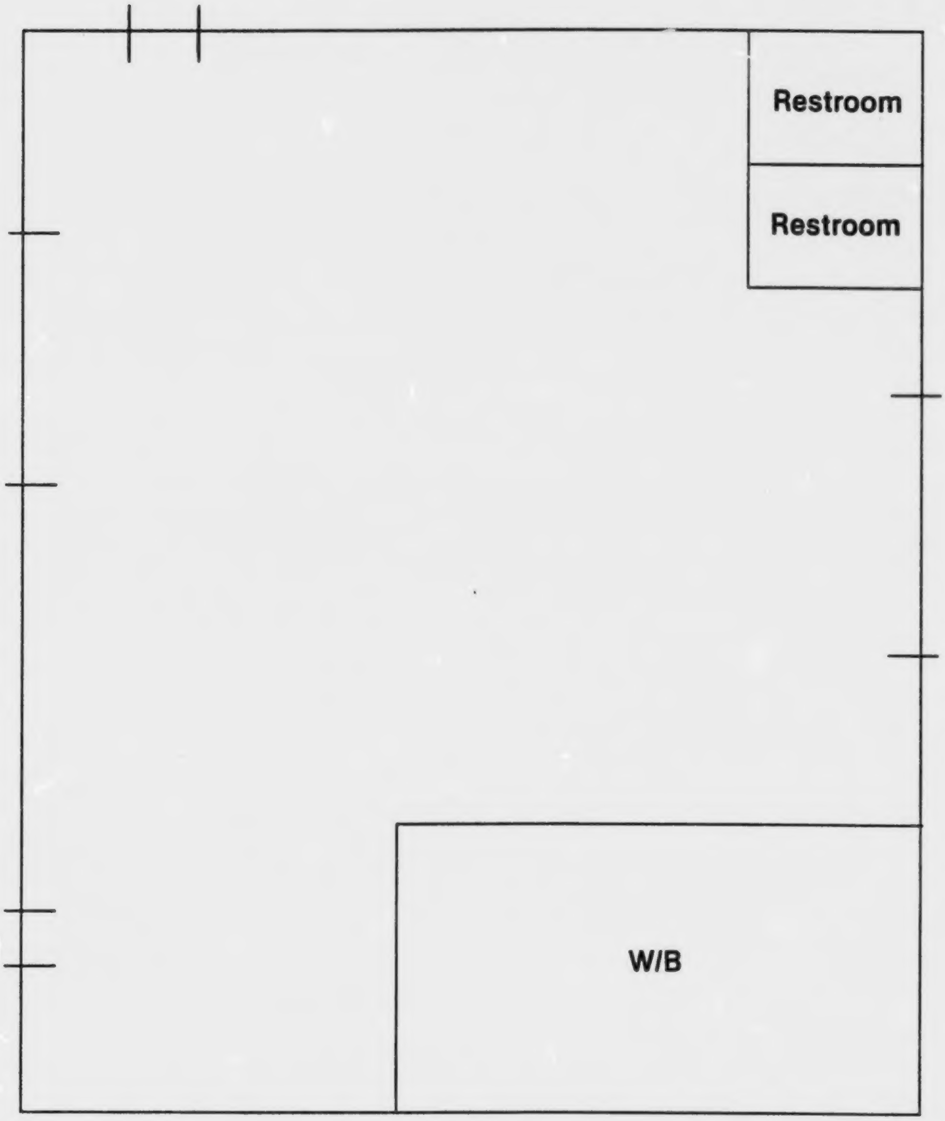
Assignment Sheet 1—Construct an Electrical Blueprint

Name ______________________________ Overall Rating __________

Evaluation Criteria	**Rating**
Ability to apply basic concepts	______
Correct symbols used	______
Diagram drawn to scale and represents correct plan specifications	______

Directions: Using the electrical symbols found in the Information Sheet and the outline on the next page, construct an electrical drawing of a garage with two restrooms, office, shop area, and wash bay. The above criteria will be used to evaluate your performance.

Assignment Sheet 1


Restroom
Restroom
W/B

Blueprint Reading and Load Calculations
Unit 1

Assignment Sheet 2—Perform Load Calculations and Determine Overcurrent Protection and Conductor Size

Name ______________________________ Overall Rating __________

Evaluation Criteria	Rating
Used sizing information correctly	______
Gave accurate answers	______

Directions: Using the following information and the *National Electrical Code*, size the fuses shown on the line diagram. The information given is for dual element time delay fuses. The above criteria will be used to evaluate your performance.

Refer to Article 220-10 for sizing feeders.
Refer to Article 430 for information on sizing motor fuses.
Refer to Article 450 for information on sizing transformer overcurrent protection.
Refer to Article 460 for information on sizing overcurrent protection for capacitors.
Refer to Article 230-95 for information pertaining to ground fault protection of service equipment.

1. **Main service**—Size the fuse according to the method described in 4.

2. **Feeder with no motor load**—The fuse size must be at least 125% of the continuous load plus 100% of the non-continuous load.

3. **Feeder with all motor loads**—The fuse must be sized at 150% of the full load current of the largest motor plus the full load current of all other motors.

4. **Feeder circuit with mixed loads**—Size the fuse at the sum of:
    a. 150% of the full load current of the largest motor,
    b. 100% of the full load current of all other motors,
    c. 125% of the continuous, nonmotor load, and
    d. 100% of the non-continuous, nonmotor load.

5. **Branch circuit with no motor load**—The fuse must be sized at least 125% of the continuous load plus 100% of the non-continuous load. (Do not size larger than the ampacity of the conductor.)

Assignment Sheet 2

6. **Motor branch circuit with overload relays**—When overload relays are sized to provide running overload protection, a and b below will provide ground fault and short circuit protection.
   a. **Motors with 1.15 service factor or 40 degrees C rise**—Size fuse at 125% of motor full load current or next higher standard size.
   b. **Motors with less than 1.15 service factor or over 40 degrees C rise**—Size the fuse at 115% of the motor full load current or the next higher standard fuse size.

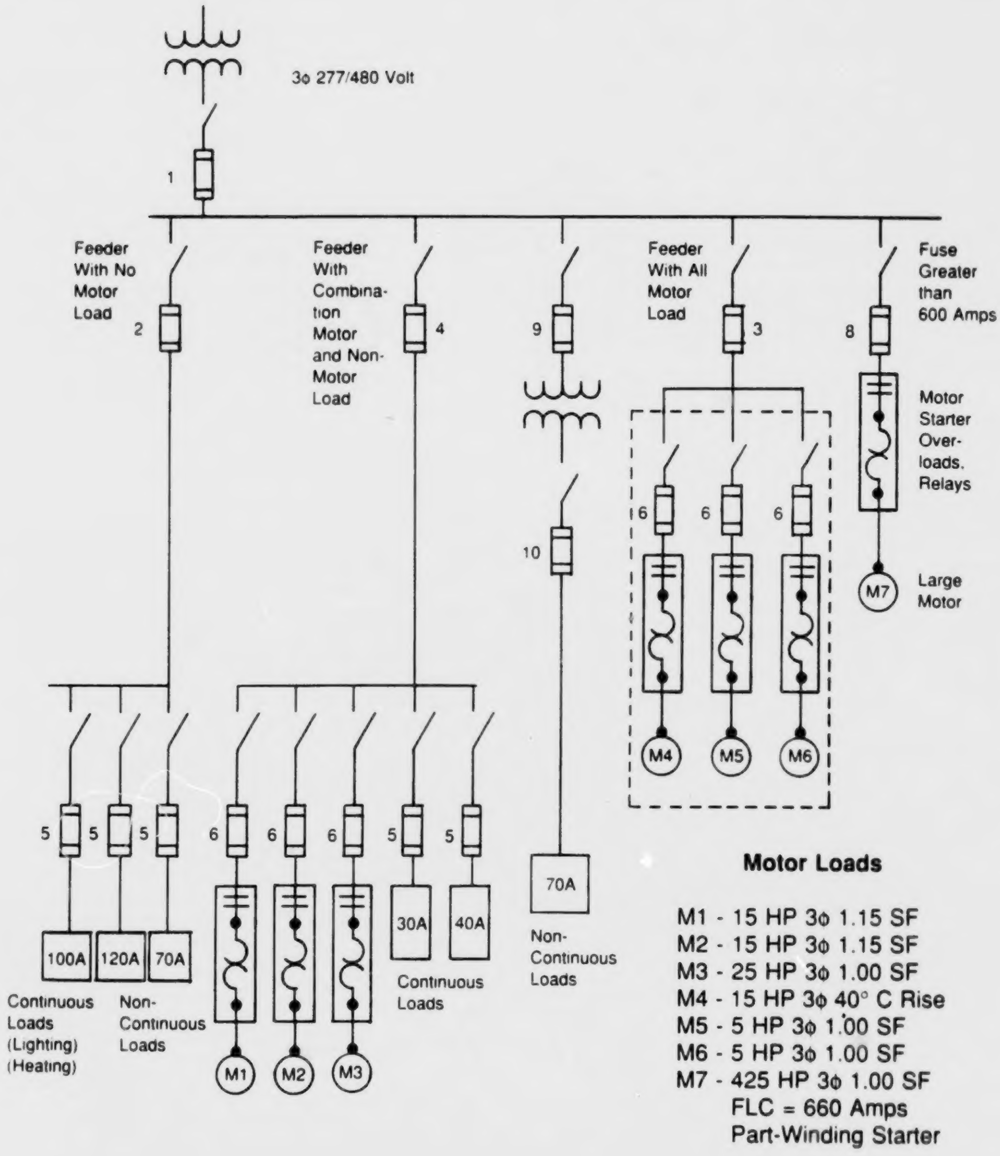
7. **Motor branch circuit with fuse protection only**—Where the fuse is the only motor protection, the following fuses will provide motor running overload and short circuit protection.
   a. **Motors with a 1.15 service factor or 40 degrees C rise**—Size the fuse at 110% to 125% of the motor full load current.
   b. **Motors with less than 1.15 service factor or over 40 degree C rise**—Size the fuse at 100% to 115% of the motor full load current.

8. **Large motor branch circuit**—For large motors (larger than 600 amperes), fuse at 150% to 225% of the full load current of the motor, depending on the starting method; i.e. part-winding starting or reduced voltage starting.

9. **Transformer primary fuse (with secondary fuse protection)**—Overcurrent protection may be sized at 250% of the transformer primary current.

10. **Transformer secondary fuse**—Size the fuse at no more than 125% of the secondary full load current.

Assignment Sheet 2


3ϕ 277/480 Volt
1
Feeder With No Motor Load
2
Feeder With Combination Motor and Non-Motor Load
4
9
Feeder With All Motor Load
3
8
Fuse Greater than 600 Amps
Motor Starter Overloads, Relays
10
6
6
6
M7
Large Motor
M4
M5
M6
5
5
5
6
6
6
5
5
100A
120A
70A
30A
40A
70A
Continuous Loads (Lighting) (Heating)
Non-Continuous Loads
Continuous Loads
Non-Continuous Loads
M1
M2
M3

Motor Loads

M1 - 15 HP 3ϕ 1.15 SF
M2 - 15 HP 3ϕ 1.15 SF
M3 - 25 HP 3ϕ 1.00 SF
M4 - 15 HP 3ϕ 40° C Rise
M5 - 5 HP 3ϕ 1.00 SF
M6 - 5 HP 3ϕ 1.00 SF
M7 - 425 HP 3ϕ 1.00 SF
FLC = 660 Amps
Part-Winding Starter

A. The 100 amp continuous lighting load will require what size fuse and what size THHN conductor?

Fuse ________________, Conductor ________________

Assignment Sheet 2

B. The 120 amp continuous lighting load will use what size fuse and what size THHN conductor?

Fuse ________________, Conductor ________________

C. The non-continuous 70 amp load will need what size THWN conductor, and what size fuse?

Fuse ________________, Conductor ________________

D. The feeder with no motor loads will require what size fuse, and what size THW conductor?

Fuse ________________, Conductor ________________

E. Motor M1 requires what size fuse and what size TW conductor?

Fuse ________________, Conductor ________________

F. Motor M2 will need a fuse of what amperage and what size TW conductor?

Fuse ________________, Conductor ________________

G. The motor marked M3 will require what size THHN branch circuit conductor and what size fuse?

Fuse ________________, Conductor ________________

H. The 30 amp continuous load will need what size fuse and what size THHN conductor?

Fuse ________________, Conductor ________________

I. The 40 amp continuous load will need what size fuse and THHN branch circuit conductor?

Fuse ________________, Conductor ________________

J. The feeder with a combination of motor and nonmotor loads will need what size fuse and THHN conductor?

Fuse ________________, Conductor ________________

K. The 70 amp non-continuous load will require what size fuse and what size THW conductor?

Fuse ________________, Conductor ________________

Assignment Sheet 2

L. The fuse and THW conductor supplying the 30 KVA transformer will need to be what size?

Fuse __________________, Conductor __________________

M. Motor M4 will require what size fuse and what size THHN conductor?

Fuse __________________, Conductor __________________

N. Motor M5 will need what size fuse and THWN conductor?

Fuse __________________, Conductor __________________

O. Motor M6 will need what size fuse and THWN branch circuit conductor?

Fuse __________________, Conductor __________________

P. The feeder with all motor loads will require what size fuse and THHN conductor?

Fuse __________________, Conductor __________________

Q. The conductor and fuse for the large motor will need to be what size?

Fuse __________________, Conductor __________________

R. The main service fuse and THWN conductor will need to be what size?

Fuse __________________, Conductor __________________

Blueprint Reading and Load Calculations
Unit 1

Assignment Sheet 3—Compute Lighting Loads

Name ______________________________ Overall Rating __________

Evaluation Criteria	**Rating**
Referred to correct sections of *NEC*	______
Computed lighting loads correctly	______

Directions: Using the *NEC*, compute the following lighting loads. The above criteria will be used to evaluate your performance.

A. Bank building with 4500 sq. ft. 120V/230, 1ϕ.

____

B. Restaurant with dining area 736 sq. ft. 277V/480, 3ϕ.

____

C. School with a classroom of 860 sq. ft. 120V/240, 3ϕ.

____

D. Auditorium in a school having 7430 sq. ft. 277V/480, 3ϕ.

____

E. Barber shop having 450 sq. ft. of floor for cutting hair at 120V/230, 1ϕ.

____

Blueprint Reading and Load Calculations
Unit 1

Assignment Sheet 4—Derate Neutral Loads

Name ______________________________ Overall Rating __________

Evaluation Criteria	Rating
Proper use of *NEC*	_____
Accurate calculations	_____
Correct answers	_____

Directions: Determine the neutral ampacity for the following problems. Refer to *NEC* Article 220-22. Show your work. The above criteria will be used to evaluate your performance.

Example: A feeder demand load totals 600 amps. A total of 120 amperes are rated 240 volts. A total of 30 amperes are feeding data processing equipment and 80 amperes are electric discharge lighting. A load of 50 amperes is a range. The remaining 320 amperes are rated at 120 volts.

Feeder neutral demand =

120 amps at 240 volts	0 amperes
50 amps range at 70%	35 amperes
320 amps of 120 volt loads	320 amperes
	355 amperes

The first 200 amperes are calculated at 100%	200 amperes
The remainder of 155 amps are calculated at 70%	108.5 amperes
30 amps of data processing equipment at 100%	30 amperes
80 amps of discharge lighting at 100%	80 amperes
The total neutral feeder demand load is	418.5 amperes

A. A 208Y/120 volt feeder demand load is 900 amperes. Ranges are 250 amps, clothes dryers are 100 amps. Seventy amps are discharge lighting, 200 amps are 208 volt loads and 30 amps are computer loads. The remaining 250 amps are 120 volt load.

Assignment Sheet 4

Neutral demand load = __________________

Total neutral demand load = __________________

B. The feeder demand load of a building is 640 amps. The system is 208Y/120 volt. The file servers and computer network are 85 amps. Electric discharge lighting is 200 amperes. An electric range is 40 amps and 200 amps are 208 volt load. The remaining load is 120 volt.

Neutral demand load = __________________

Total neutral demand load = __________________

C. Of the total 400 amperes of feeder demand load, 100 amperes are electric ranges. A total of 50 amperes are dryers. Discharge lighting is 50 amperes and a total of 30 amperes are 240 volt load. The remaining 170 amperes are 120 volt load.

Neutral demand load = __________________

Total neutral demand load = __________________

Assignment Sheet 4

D. Counter mounted cooking equipment is 40 amps of the total 300 amp feeder demand load. Clothes dryers are 30 amperes, 200 amps are 240 volt load and the remainder is 120 volt loads.

Neutral demand load = ____________________

Total neutral demand load = ____________________

Blueprint Reading and Load Calculations
Unit 1

Assignment Sheet 5—Determine Maximum Numbers of Conductors in Conduit

Name ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
Ability to apply basic concepts	______
Correct answers	______

Directions: Determine the maximum number of conductors in conduit for the problems below. The above criteria will be used to evaluate your performance.

A. Conduit fill for #12 THW wires in a ½" conduit

____

B. Conduit fill for #8 RHW wires in a 1¼" conduit

____

C. Conduit fill for #14 TW wires in a 2½" conduit

____

D. Conduit fill for #3/0 THW wires in a 3" conduit

____

E. Conduit fill for #10 THWN wires in a 1" conduit

____

Blueprint Reading and Load Calculations
Unit 1

Assignment Sheet 6—Determine Wire Sizes to Prevent Voltage Drop

Name ______________________________ Overall Rating __________

Evaluation Criteria	**Rating**
Proper use of *NEC*	_____
Accurate calculations	_____
Correct answers	_____

Directions: Voltage drop is directly proportional to resistance and current. Therefore the longer a conductor and the greater the current, the greater the voltage drop will be. While the *NEC* mandates no requirements concerning voltage drop, it does provide three recommendations to size conductors to prevent an excessive amount of voltage drop. See Article 210-19 (a) (FPN No. 3), Article 215-2 (b) (FPN No. 2), and Article 310-15 (FPN). Basically, these three recommendations limit voltage drop on branch circuits to 3%, voltage drop on feeders is also limited to 3%, and a 5% maximum voltage drop is recommended overall. Using a constant (K) of 12 and the following formulas, determine the proper wire size needed to prevent the voltage drop from exceeding 3%. Show your work. The above criteria will be used to evaluate your performance.

For single phase use: $VD = \frac{2\ (K)\ (L)\ (I)}{CM}$

For three phase use: $VD = \frac{(K)\ (L)\ (I)\ (1.732)}{CM}$

K = A constant of 12, L = Length in feet, I = Current in amperes

A. What size copper conductors are required for a 240 volt, 2-wire branch circuit, with an 80 amp load? The one way length is 115 feet.

Wire size = ________________

Assignment Sheet 6

B. Determine the copper wire size for a branch circuit pulling 22 amps located 150 feet from the source. The voltage is 230.

Wire size = ____________________

C. A feeder has a load of 125 amps at 240 volts, and it is 100 feet from the source. What size wire is needed?

Wire size = ____________________

D. A 460 volt 3 phase feeder will serve a load of 300 amps. The distance from the point of attachment with the power company is 230 feet. What size conductor will be required?

Wire size = ____________________

Tools and Equipment
Unit 2

Objective Sheet

Unit Objective

After completing this unit, the student should be able to identify and use tools and equipment found in electrical trades. The student should demonstrate these competencies by completing the job sheets, and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to tools and equipment with their correct definitions.
2. Identify types of conduit benders.
3. Identify wire termination tools.
4. Identify wire and cable pulling equipment.
5. Identify conduit cutting and threading tools.
6. Identify knockout cutters.
7. List power actuated tools used in the electrical trade.
8. List types of excavation equipment.
9. Bend, cut, ream, and thread one-half-inch rigid metal conduit. (Job Sheet 1)
10. Bend EMT stub-ups. (Job Sheet 2)
11. Make back-to-back bends on one-half-inch EMT. (Job Sheet 3)
12. Make offset bends on one-half-inch EMT. (Job Sheet 4)
13. Bend and install one-half-inch EMT. (Job Sheet 5)
14. Bend a three-point saddle on one-half-inch EMT. (Job Sheet 6)
15. Bend a four-point saddle on one-half-inch EMT. (Job Sheet 7)
16. Cut, ream, offset, and install connectors on one-half-inch PVC. (Job Sheet 8)

Tools and Equipment
Unit 2

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.

2. Review Teaching Suggestions section that follows. Plan for classroom activities.

3. Plan for students with special needs.

4. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.

5. Develop teaching plan. Adjust for different learning styles.

6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.

8. Discuss unit and specific objectives.

9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.

10. Discuss the job sheets. Review criteria for evaluation of these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

12. Make copies of the written test. Add or modify test items as needed.

13. Give written test.

14. Record job sheet ratings and written test scores on the Unit Evaluation Form. Add any additional assignments or supplemental activities that should be part of the unit evaluation.

15. Reteach and retest as required.

Suggested Activities

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Have local equipment company demonstrate excavation equipment. Skill area: **listening**.
2. Take a tour of a factory to look at bends on piping. Allow for student comments and questions. Skill area: **oral communication**.
3. Have supply house bring different kinds of tools and equipment to demonstrate. Conduct a question and answer period following the demonstration. Skill areas: **listening** and **oral communication**.
4. Review safety rules relating to proper use of equipment. Ask students to write safety rules in their own words to reinforce learning. Skill area: **writing**.

Resources Used in Developing This Unit

1. Greenlee tool catalog. Rockford, IL: Greenlee Tool Company.
2. Kaltwasser, Stan and Gary Flowers. *Commerical and Industrial Wiring*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1988.
3. Taylor, Mark. *Residential Wiring*. Revised. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1983.
4. Teague, Cash and Garner Pewewardy. *Industrial Electricity: In-Plant Distribution*. Stillwater, OK: Oklahoma Curriculum and Instructional Materials Center, 1984.

Suggested Supplemental Resources

1. Croft, Terrell and Wilford I. Summers. *American Electrician's Handbook*, 11th Ed. New York: McGraw-Hill Book Company, 1987.
2. Earley, Mark W., John M. Caloggero and Richard H. Murray. *NEC Handbook 1993*. Quincy, MA: National Fire Protection Association, 1992.
3. *National Electrical Code 1993*. Quincy, MA: National Fire Protection Association, 1992.
4. O'Riley, Ronald P. *Illustrated Changes in the 1993 National Electrical Code*. Albany, NY: Delmar Publishers, Inc., 1993.

Suggested Activities

Instructions for Evaluating Student Performance

Assignment Sheets—Be sure the student understands the criteria on which the evaluation is based. Assign a point value to each criterion and convert the total points to a percentage for grading.

Job Sheets—Be sure the student understands the criteria on which the evaluation is based. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher or student edition. Then observe the student performing the procedure. Rate both process and product.

> Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.
>
> Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. Complete the rating by assigning a point value to each criterion and by converting the point total to a percentage for grading. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) which best fits your program needs.

Option A

4 - Skilled—Can perform job with no additional training.
3 - Moderately skilled—Has performed job during training program; limited additional training may be required.
2 - Limited skill—Has performed job during training program; additional training is required to develop skill.
1 - Unskilled—Is familiar with process, but is unable to perform job.

Option B

Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

Tools and Equipment
Unit 2

Answers to Written Test

1. a. 16
   b. 1
   c. 7
   d. 5
   e. 3
   f. 15
   g. 14
   h. 9
   i. 2
   j. 10
   k. 12
   l. 13
   m. 11
   n. 4
   o. 6
   p. 8

2. a. (1) Hickey bender
      (2) EMT bender
      (3) One shot offset

   b. (1) Table bender
      (2) Manual hydraulic bender
      (3) Rigid bender

   c. (1) Rigid bender
      (2) EMT bender

   d. (1) Electric PVC heater
      (2) PVC blanket
      (3) PVC pipe plugs

3. a. (1) Ratchet cutters
      (2) Manual cutters
      (3) Hydraulic cutters

   b. (1) Combination tool
      (2) Adjustable wire strippers
      (3) Stripper/cutter
      (4) Hydraulic crimper

   c. (1) Cable bender
      (2) Cable stripper

4. a. Pulling rope
   b. Fish tape
   c. Manual puller
   d. Pulling sleeve
   e. Jet line
   f. Electric puller

Answers to Written Test

5. a. (1) Band saw
      (2) Hacksaw
      (3) Portable band saw

   b. (1) Pipe stand
      (2) Electric die set
      (3) Manual die set
      (4) Electric portable threader

6. a. Ratchet K.O.
   b. Hydraulic K.O.
   c. C-punch K.O.
   d. Stud punch
   e. Manual K.O.

7. a. Hammer drill
   b. Powder actuated device

8. a. Trencher
   b. Backhoe

Tools and Equipment
Unit 2

Written Test

Name ______________________________ Score ______________

1. Match the terms on the right with their correct definitions.

______a. Machine used to dig trenches

______b. Machine used to dig ditches on construction sites

______c. Used to bore through concrete

______d. Used to cut conduit for electrical installations

______e. Used to bend large conductors

______f. Used to thread pipe so electrical fittings may be attached to conduit

______g. Used to remove insulation from conductors

______h. Used to cut holes, slots, and cuts in electrical boxes and studs

______i. Used to bend pipe used in electrical trades

______j. Used to pull multiple and large conductors through a conduit

______k. Attaches around the end of conductors so they may be pulled through a conduit

______l. Uses charges that shoot studs and tie downs into concrete, metal, and wood

______m. Wax-based product that allows the conductors to pass through the conduit causing less friction

1. Backhoe
2. Bender
3. Cable bender
4. Cable cutters
5. Cutting tools
6. Fish tape
7. Hammer drill
8. Jet line
9. Knockout cutter
10. Pulling equipment
11. Pulling lube
12. Pulling sleeve
13. Powder actuated device
14. Strippers
15. Threading tools
16. Trencher

Written Test

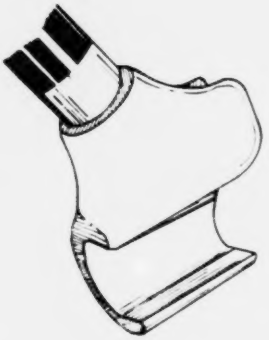
_______n. Used to cut conductors

_______o. Long tape of steel, nylon, or other material used to push or pull conductors into a raceway

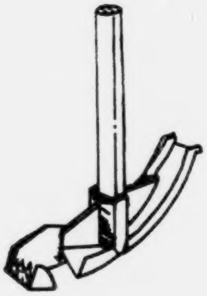
_______p. Line sucked or blown through a conduit by positive or negative pressure so a rope or tape can be pulled through a conduit

2. Identify the following types of conduit benders.

   a. Manual conduit benders



(1) ______________________



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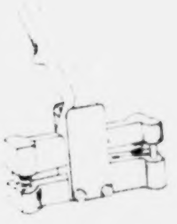
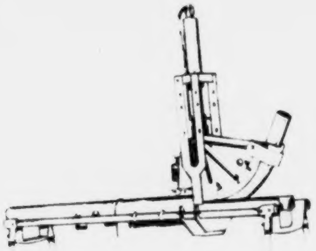
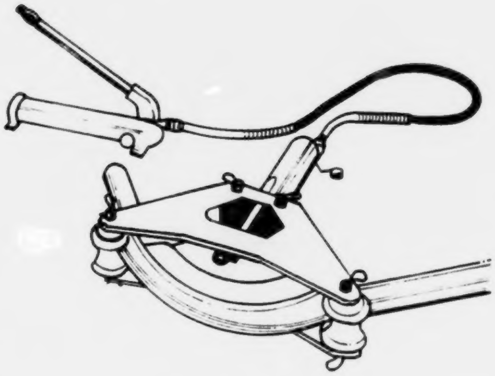


(3) ______________________

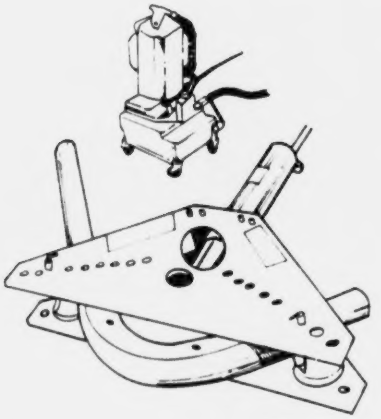
Written Test

b. Hydraulic conduit benders





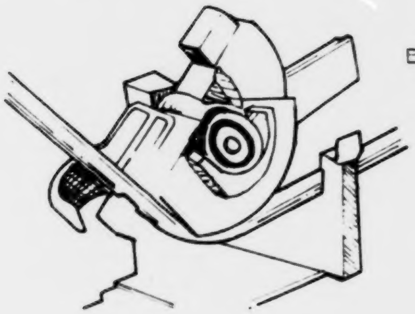
(1) ______________________ (2) ______________________

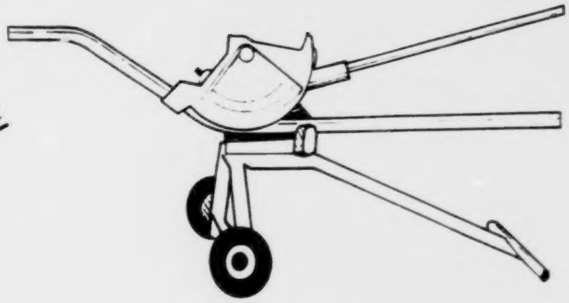


(3) ______________________

Written Test

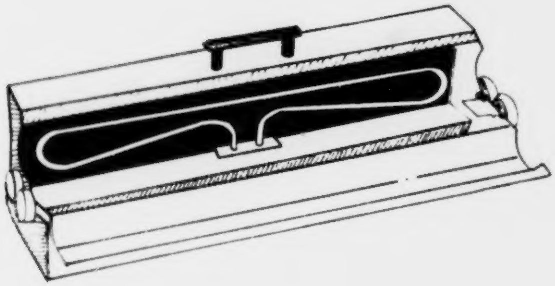
c. Mechanical conduit benders

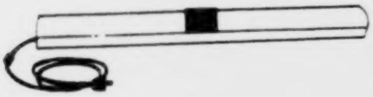




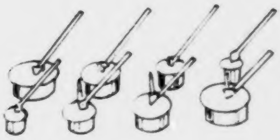
(1) ______________________ (2) ______________________

d. PVC bending equipment





(1) ______________________ (2) ______________________

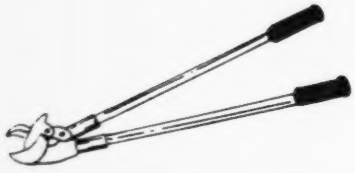


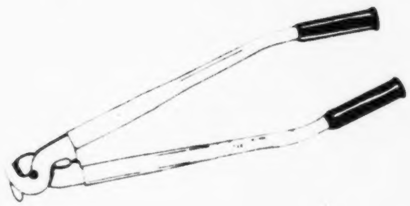
(3) ______________________

Written Test

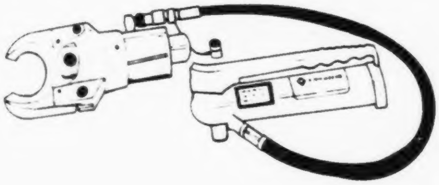
3. Identify the wire termination tools shown below.

a. Cable cutters



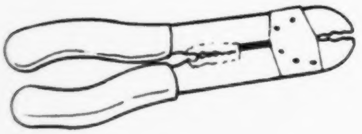


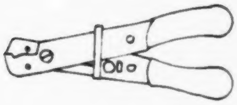
(1) ______________________________ (2) ______________________________



(3) ______________________________

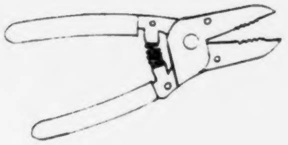
b. Wire strippers and crimpers

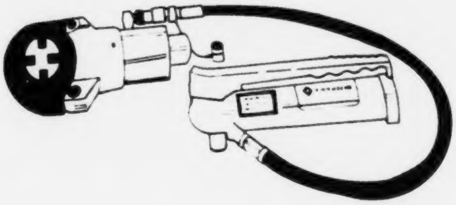




(1) ______________________________ (2) ______________________________

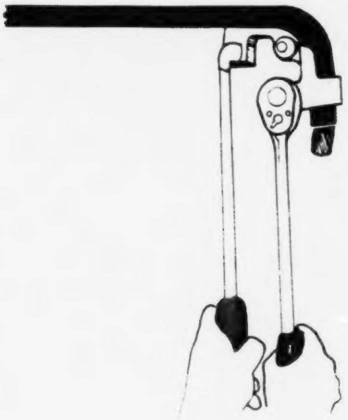
Written Test

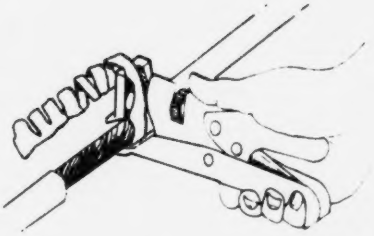




(3) ____________________ (4) ____________________

c. Cable stripper and bender

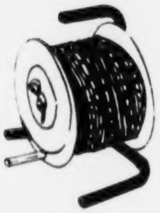




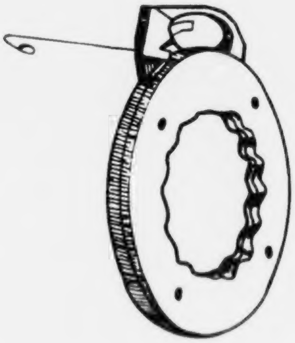
(1) ____________________ (2) ____________________

Written Test

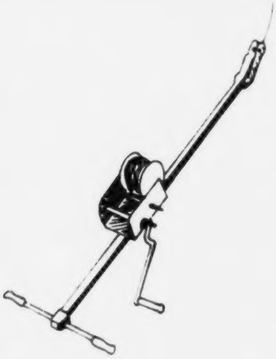
4. Identify the wire and cable pulling equipment shown below.



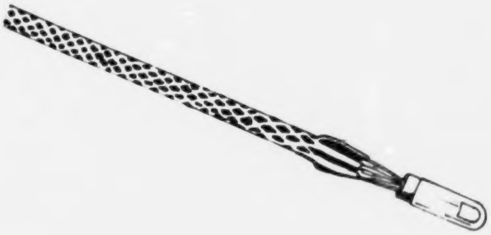
a. ______________________



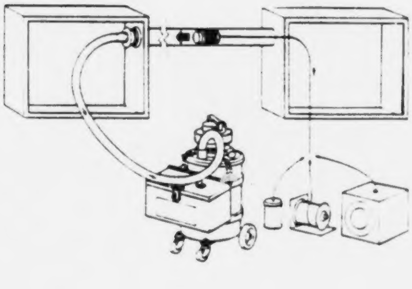
b. ______________________



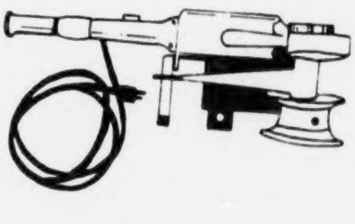
c. ______________________



d. ______________________



e. ______________________

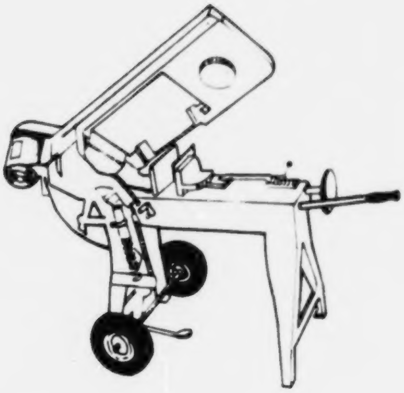


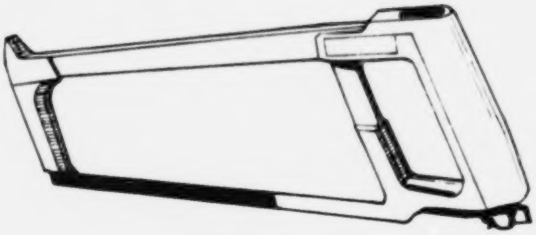
f. ______________________

Written Test

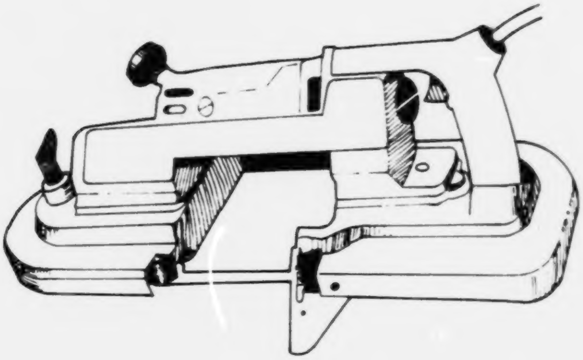
5. Identify the conduit cutting and threading tools shown below.

   a. Cutting tools





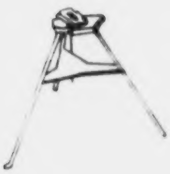
(1) ____________________ (2) ____________________



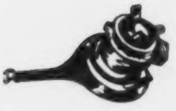
(3) ____________________

Written Test

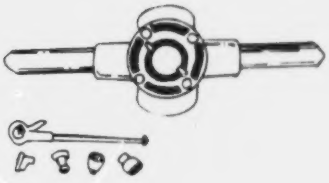
b. Threading tools



(1) ______________________________



(2) ______________________________



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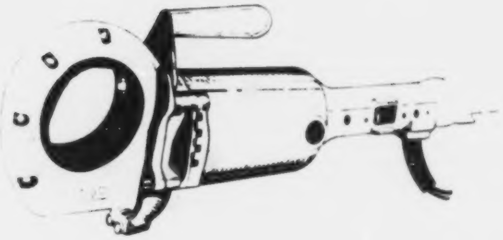
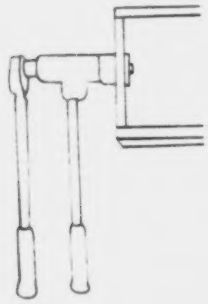


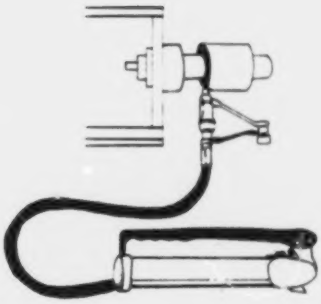
(4) ______________________________

Written Test

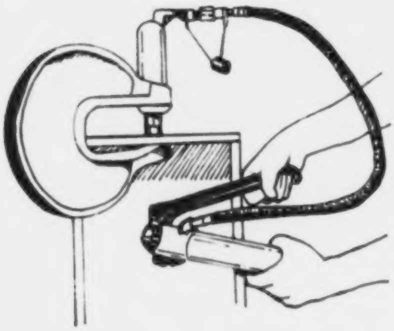
6. Identify the following knockout cutters.



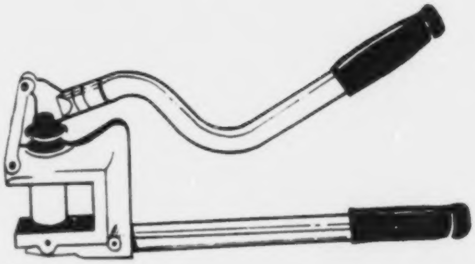
a. ______________________



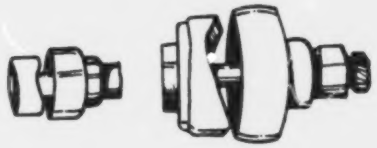
b. ______________________



c. ______________________



d. ______________________



e. ______________________

Written Test

7. List two power actuated tools used in the electrical trade.

   a. ____

   b. ____

8. List two types of excavation equipment.

   a. ____

   b. ____

*Permission to duplicate this test is granted.

Tools and Equipment
Unit 2

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Job Sheet 1—Bend. Cut. Ream. and Thread One-Half-Inch Rigid Metal Conduit Rating ______

Comments: ____

Job Sheet 2— Bend EMT Stub-Ups Rating ______

Comments: ____

Job Sheet 3—Make Back-to-Back Bends on One-Half-Inch EMT Rating ______

Comments: ____

Job Sheet 4—Make Offset Bends on One-Half-Inch EMT Rating ______

Comments: ____

Job Sheet 5—Bend and Install One-Half-Inch EMT Rating ______

Comments: ____

Job Sheet 6—Bend a Three-Point Saddle on One-Half-Inch EMT Rating ______

Comments: ____

Job Sheet 7—Bend a Four-Point Saddle on One-Half-Inch EMT Rating ______

Comments: ____

Unit Evaluation Form

Job Sheet 8—Cut. Ream. Offset. and Install Connectors on One-Half-Inch PVC

Rating ______

Comments: ____

____

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ____

____

Teacher Signature ______________________ Date __________

Student Signature ______________________ Date __________

*Permission to duplicate this form is granted.

Tools and Equipment
Unit 2

Information Sheet

1. **Terms and definitions**

   a. **Backhoe** — Machine used to dig ditches on construction sites

   b. **Bender** — Used to bend pipe used in electrical trades

   c. **Cable bender** — Used to bend large conductors

   d. **Cable cutters** — Used to cut conductors

   e. **Cutting tools** — Used to cut conduit for electrical installations

   f. **Fish tape** — Long tape of steel, nylon, or other material used to push or pull conductors into a raceway

   g. **Hammer drill** — Used to bore through concrete

   h. **Jet line** — Line sucked or blown through a conduit by positive or negative pressure so a rope or tape can be pulled through a conduit

   i. **Knockout cutter** — Used to cut holes, slots, and cuts in electrical boxes and studs

   j. **Powder actuated device** — Uses charges that shoot studs and tie downs into concrete, metal, and wood

   k. **Pulling equipment** — Used to pull multiple and large conductors through a conduit; may be manual or electrically operated

   l. **Pulling lube** — Wax-based product that allows the conductors to pass through the conduit causing less friction

   m. **Pulling sleeve** — Attaches around the end of conductors so they may be pulled through a conduit

   n. **Strippers** — Used to remove insulation from conductors

   o. **Threading tools** — Used to thread pipe so electrical fittings may be attached to conduit

   Note: Electrical threads are straight; plumbing threads are tapered.

   p. **Trencher** — Machine used to dig trenches

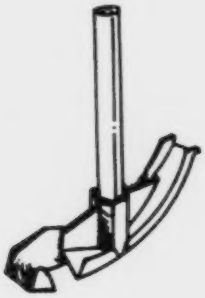
Information Sheet

2. Types of conduit benders

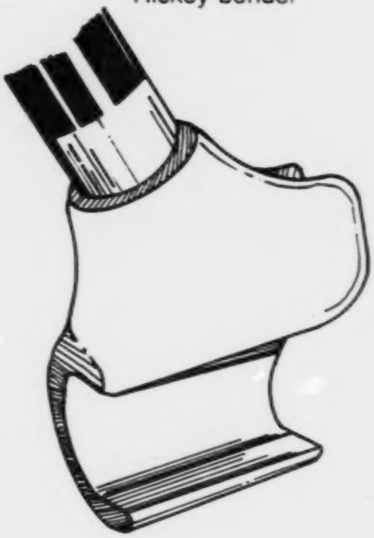
Note: There are four basic types of benders used in the electrical field: manual, hydraulic, mechanical, and PVC.

a. Manual conduit benders

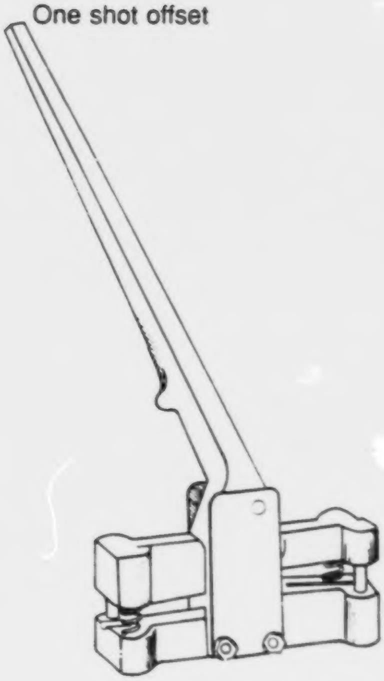
- EMT bender



- Hickey bender



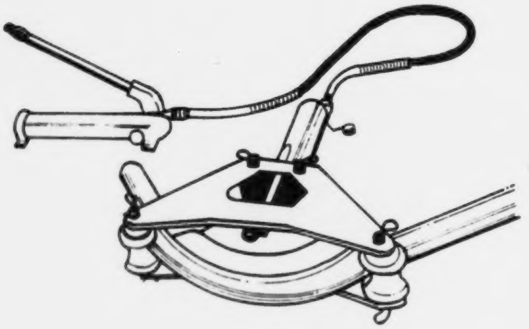
- One shot offset



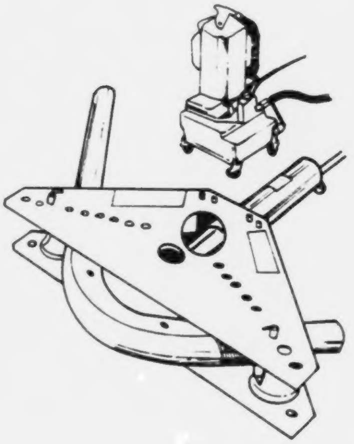
Information Sheet

b. Hydraulic conduit benders

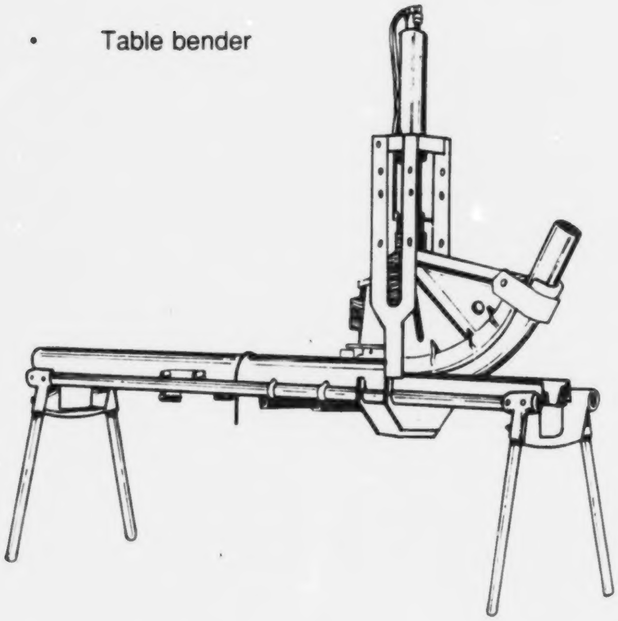
- Manual hydraulic bender



- Rigid bender



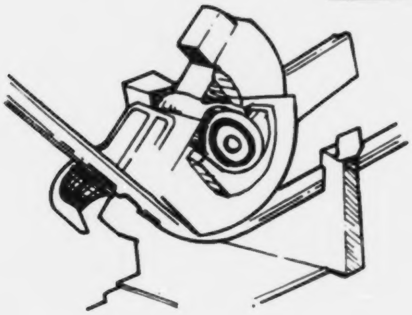
- Table bender



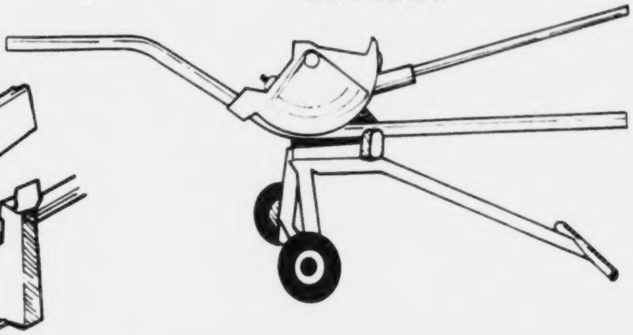
Information Sheet

c. Mechanical conduit benders

- Rigid bender

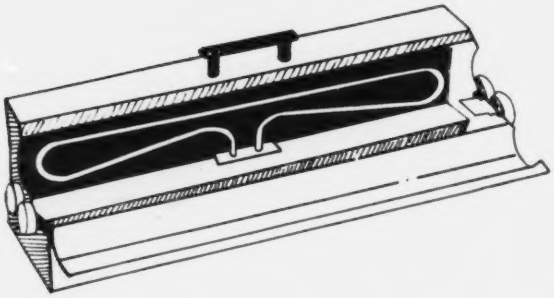


- EMT bender

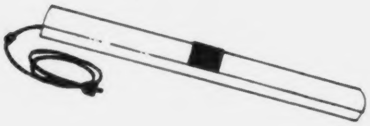


d. PVC Bending equipment

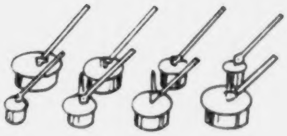
- Electric PVC heater



- PVC blanket



- PVC pipe plugs



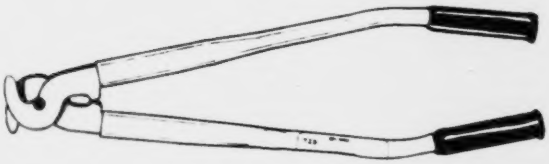
Information Sheet

3. Wire termination tools

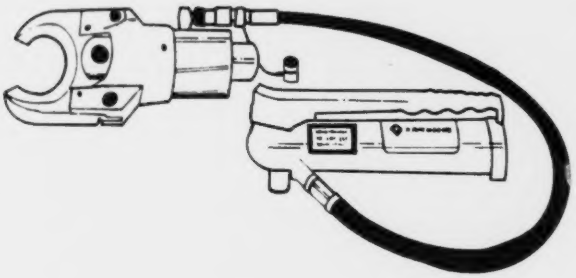
Note: When terminating copper, always use copper or copper clad lugs. When terminating aluminum, always use aluminum lugs.

a. Cable cutters

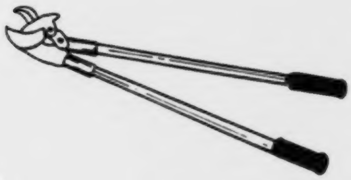
- Manual cutters



- Hydraulic cutters

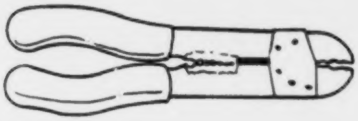


- Ratchet cutters

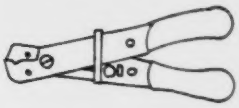


b. Wire strippers and crimpers

- Combination tool

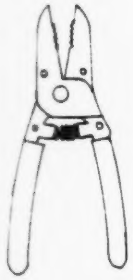


- Adjustable wire strippers

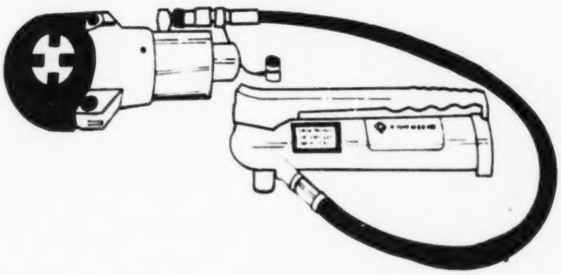


Information Sheet

- Stripper/cutter

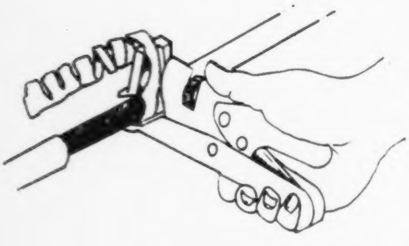


- Hydraulic crimper

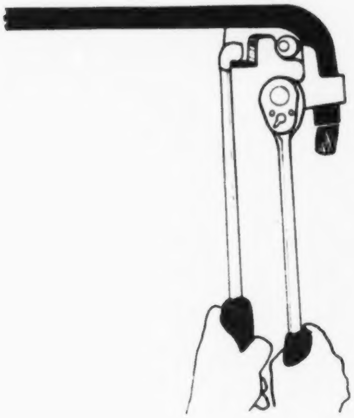


c. Cable stripper and bender

- Cable stripper



- Cable bender

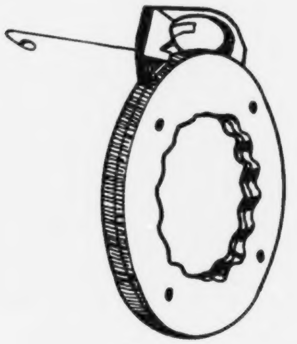


Information Sheet

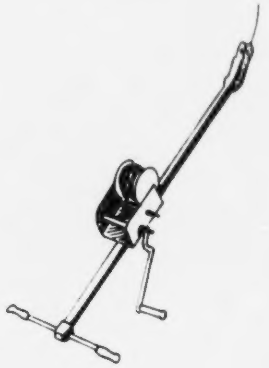
4. Wire and cable pulling equipment

Note: Pulling wire and cable through a conduit requires special tools. Tool use will vary depending on the conductor distance, size, and length.

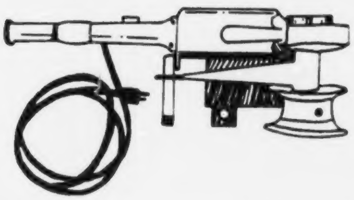
a. Fish tape



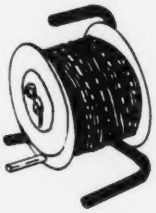
b. Manual puller



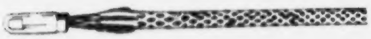
c. Electric puller



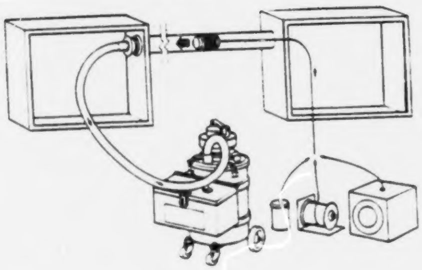
d. Pulling rope



e. Pulling sleeve

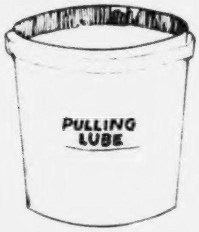


f. Jet line



Information Sheet

g. Pulling lube

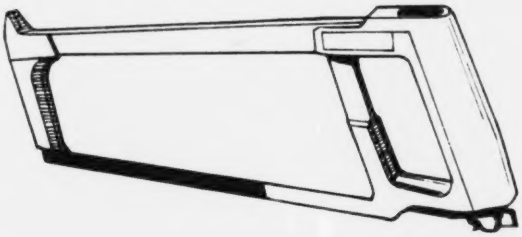


5. **Conduit cutting and threading tools**

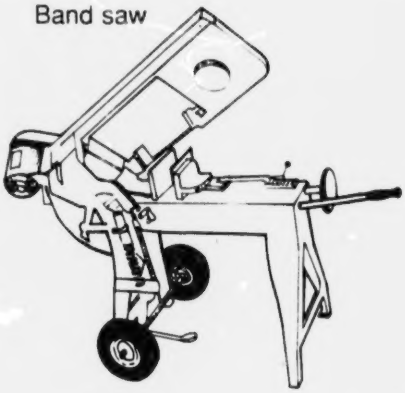
> **Caution: Equipment used in cutting and threading can be dangerous. Use caution when operating.**

a. Cutting tools

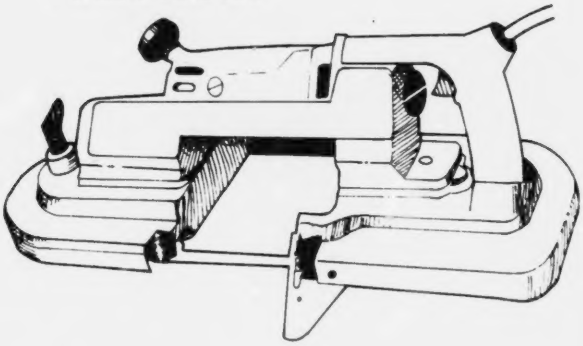
- Hacksaw



- Band saw



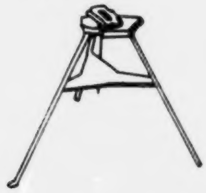
- Portable band saw



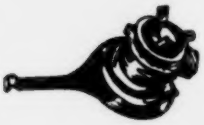
Information Sheet

b. Threading tools

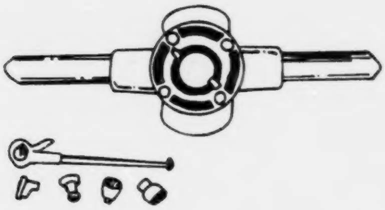
- Pipe stand



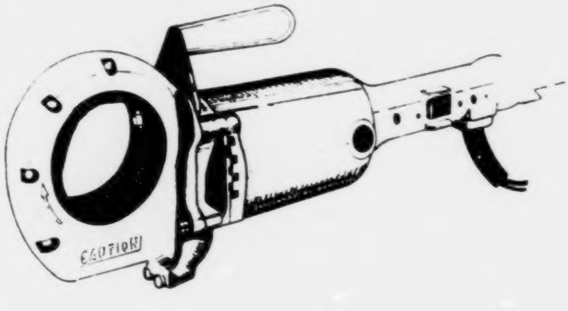
- Electric die set



- Manual die set



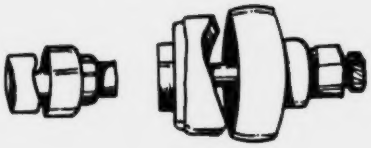
- Electric portable threader



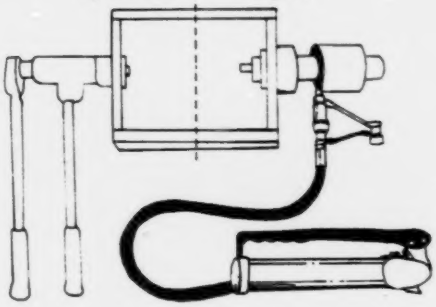
6. Knockout cutters

Note: Knockout cutters are used for making holes, slots, and cuts for electrical devices to be installed.

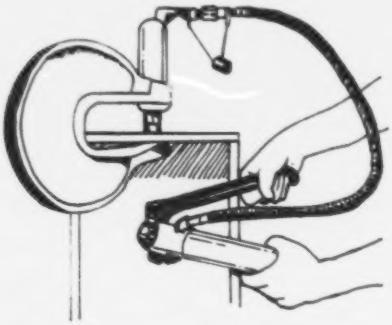
a. Manual K.O.



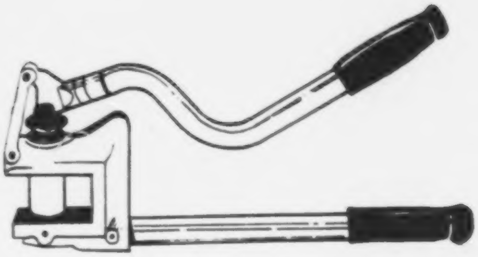
b. Ratchet K.O. (left) and hydraulic K.O. (right)



c. C-punch K.O.



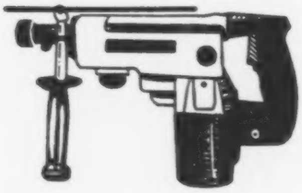
d. Stud punch



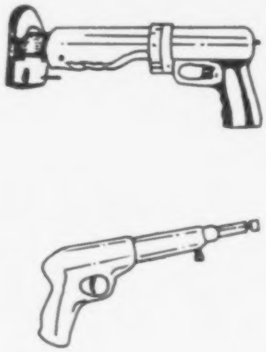
7. **Power actuated tools**

Caution: Never use these tools without first taking a safety test and getting approval from the instructor. These tools can be extremely dangerous.

a. Hammer drill



b. Powder actuated device

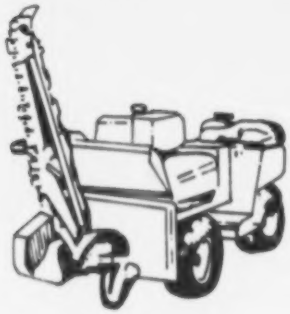


Information Sheet

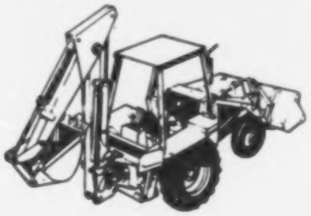
8. Excavation equipment

Note: Special training must be taken before operating excavation equipment. Always have a locator on site before digging. This prevents cutting of gas, electrical, and telephone lines.

a. Trencher



b. Backhoe



Tools and Equipment
Unit 2

Job Sheet 1 — Bend, Cut, Ream, and Thread One-Half-Inch Rigid Metal Conduit

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Proper cut	______
90° bend on pipe	______
Correct thread depth and length	______
Conduit reamed	______
Workmanship	______
Compliance to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Eye protection
Hacksaw
10-foot piece of ½-inch rigid metal conduit
¾-inch EMT bender with handle
Reaming tool
½-inch conduit pipe die
Cutting oil
Hickey pipe vise
Measuring tape
Marking pencil

Job Sheet 1

B. Procedure

☐ 1. Observe safety rules throughout this procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Put on eye protection.

☐ 4. Measure and mark conduit for 18-inch stub-up.

Note: Check ¾-inch EMT bender for take up.

☐ 5. Place bender on conduit with "B" on bend mark.

☐ 6. Bend conduit, holding **heavy** foot pressure on bender.

☐ 7. Use hacksaw to cut off stub-up and 90-degree bend.

☐ 8. Place cut off piece of conduit in vise for threading.

☐ 9. Ream inside ends of conduit.

☐ 10. Thread end of stub, using ½-inch conduit pipe die and plenty of cutting oil.

☐ 11. Remove die and examine threads.

Note: If the die was good and an adequate amount of cutting oil was used, the threads will be smooth with sharp ridges.

☐ 12. If threads are ragged, cut them off and repeat steps 10 and 11.

☐ 13. Return tools and materials to proper storage.

☐ 14. Clean the work area.

Evaluator's comments: ____

____

____

Tools and Equipment
Unit 2

Job Sheet 2 — Bend EMT Stub-Ups

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Stub measured 11″ from floor	______
EMT cut square	______
Reamed properly	______
Workmanship	______
Compliance to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Measuring tape
Marking pencil
½-inch EMT bender with handle
10-foot piece of ½-inch EMT
Hacksaw
Eye protection

B. Procedure

Note: All benders are not marked alike. check your bender, and use measurements given for it.

☐ 1. Observe safety rules throughout this procedure.

☐ 2. Check out proper tools and materials.

Job Sheet 2

☐ 3. Measure and mark tubing 11 inches from end to be bent.

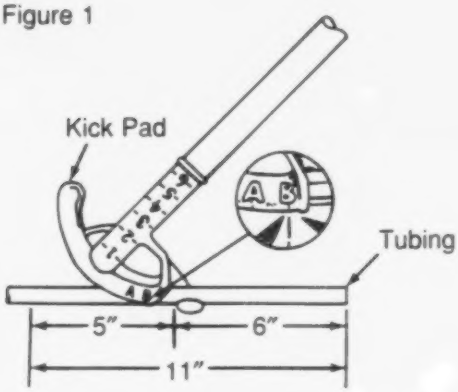
☐ 4. Subtract 5 inches from mark made in step 1; mark this measurement.

Note: This measurement varies for each size tubing.

☐ 5. Put on eye protection.

☐ 6. Place conduit bender on tubing in position to bend toward unmarked end of tubing.

Figure 1



☐ 7. Place bender mark "B" on mark made in step 4.

☐ 8. Position tubing and bender on the floor with one foot on the bender heel, keeping bender mark "B" on the conduit mark.

☐ 9. Place heavy foot pressure on the bender kick pad.

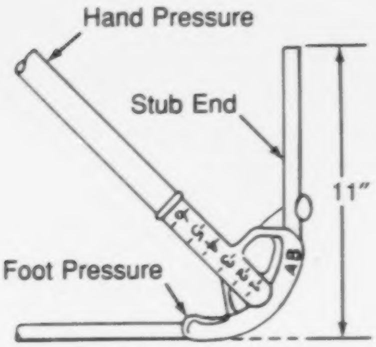
☐ 10. Make one sweeping movement of the bender handle until the tubing is perpendicular to the floor.

☐ 11. Before removing the bender, measure the height of tubing end above the floor.

Note: If the bend is an exact 90 degrees, the end will be 11 inches above the floor.

Job Sheet 2

Figure 2


Hand Pressure
Stub End
11"
Foot Pressure
AB

☐ 12. Remove the bender.

☐ 13. Use a hacksaw to cut off the bent end of tubing.

☐ 14. Practice the procedure by repeating steps 3 through 13 as many times as possible, using up the 10 feet of tubing.

☐ 15. Return tools and materials to proper storage.

☐ 16. Clean the work area.

Evaluator's comments: ______________________________

____

____

Tools and Equipment
Unit 2

Job Sheet 3 — Make Back-to-Back Bends on One-Half-Inch EMT

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Bent to proper dimensions	______
Straight cut	______
EMT reamed properly	______
Workmanship	______
Compliance to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

10 feet of ½-inch EMT
Republic bender, Catalog #1472 or similar
Hacksaw
Measuring tape
Marking pencil
Eye protection

B. Procedure

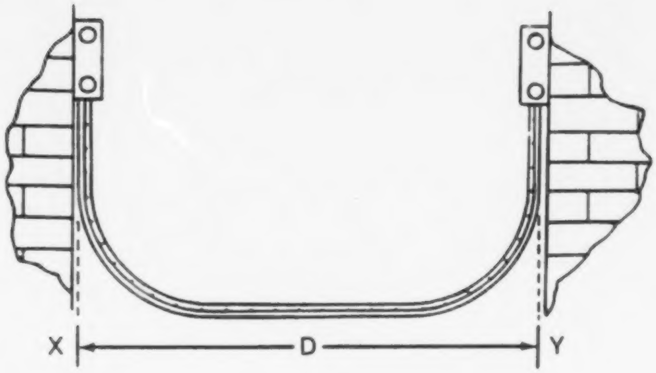
☐ 1. Observe safety rules throughout this procedure.

☐ 2. Check out proper tools and materials.

Job Sheet 3

☐ 3. Measure 30 inches for distance D shown in Figure 1.

Figure 1



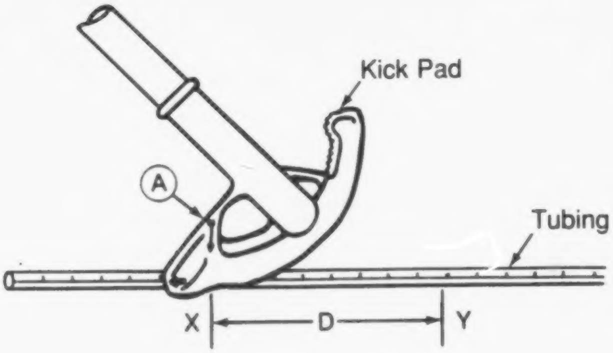
Used with permission of Republic Steel Corporation.

☐ 4. Mark tubing at points X and Y (D distance) shown in Figure 1.

☐ 5. Put on eye protection.

☐ 6. Place bender point "A" on tubing at point X as shown in Figure 2.

Figure 2



☐ 7. Place heavy foot pressure on bender kick pad.

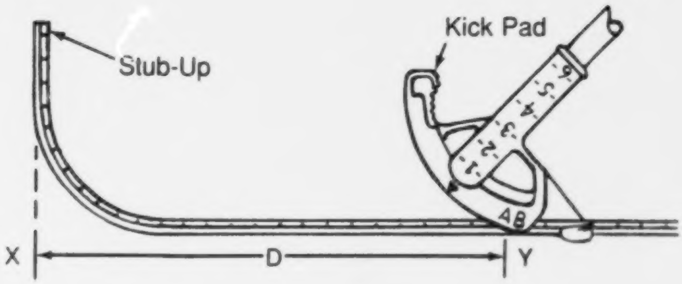
☐ 8. Make one sweeping movement with bender handle until tubing is perpendicular to floor.

Job Sheet 3

☐ 9. Remove bender.

☐ 10. Place bender mark "A" on tubing at point Y in position to bend *toward* point X; make sure that stub-up (made in step 5) points straight up.

Figure 3



Used with permission of Republic Steel Corporation.

☐ 11. Repeat steps 7 and 8.

☐ 12. Remove bender.

☐ 13. Check distance from back to back.

Note: If bender point "A" did not slip and bends are truly 90 degrees, the measurement will be 30 inches, the distance of D.

☐ 14. Use hacksaw to cut off bent end of tubing.

☐ 15. Practice procedure by repeating steps 3 through 14 as many times as possible, using up the 10 feet of tubing.

☐ 16. Return tools and materials to proper storage.

☐ 17. Clean the work area.

Evaluator's comments: ____________________

____

____

Tools and Equipment
Unit 2

Job Sheet 4 — Make Offset Bends on One-Half-Inch EMT

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
Practiced safety rules throughout procedure	______
Accurate bends	______
Cut EMT straight	______
Reamed EMT	______
Workmanship	______
Compliance to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

½-inch EMT bender
10 feet of ½-inch EMT
Measuring tape
Marking pencil
Hacksaw
Eye protection

B. Procedure

☐ 1. Observe safety rules throughout this procedure.

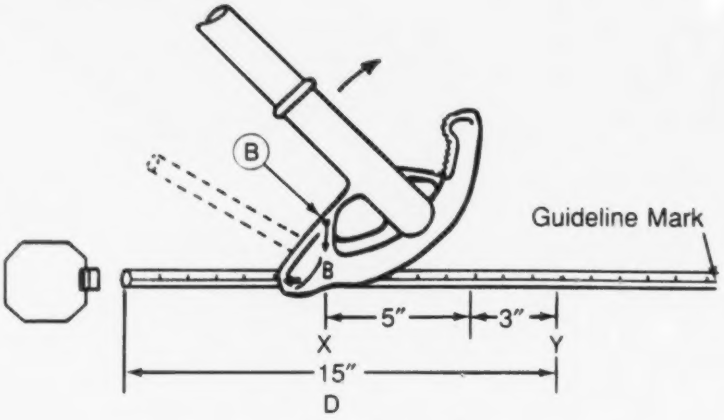
☐ 2. Check out proper tools and materials.

☐ 3. Measure 15 inches from end of tubing for distance D shown in Figure 1.

Note: This measurement represents the distance from the outlet box to the object to be passed.

Job Sheet 4

Figure 1



Used with permission of Republic Steel Corporation.

☐ 4. Mark tubing at point Y shown in Figure 1.

☐ 5. Measure back 8 inches from point Y, and mark tubing at this measurement to establish point X.

Note: The 8-inch number is determined by taking half the height of the offset and adding 5 inches.

☐ 6. Put on eye protection.

☐ 7. Place bender point "B" on tubing at point X, with bender in position to bend toward object to be passed.

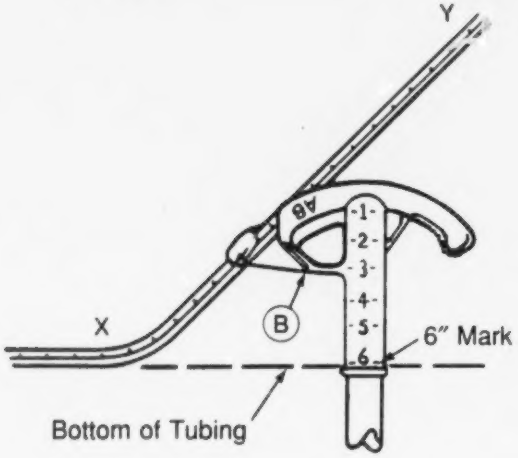
☐ 8. Make 45-degree bend.

☐ 9. Remove bender.

Job Sheet 4

☐ 10. Reverse the tubing and slip the end of it through holding hook on bender so that the lower part of the 45-degree bend is in line with the 6-inch depth measurement on side of bender as shown in Figure 2; mark tubing at point B.

Figure 2



Used with permission of Republic Steel Corporation.

☐ 11. Remove bender, and place on tubing with bender point "B" at 6-inch mark.

☐ 12. Make 45-degree bend.

☐ 13. Remove bender.

Note: This step completes the offset.

☐ 14. Use hacksaw to cut off offset.

☐ 15. practice procedure at least five times, making 1-inch, 2-inch, 3-inch, 4-inch, and 5-inch offsets.

☐ 16. Return equipment and materials to proper storage.

☐ 17. Clean the work area.

Evaluator's comments: ______________________________

____

____

Tools and Equipment
Unit 2

Job Sheet 5 -- Bend and Install One-Half-Inch EMT

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Pipe measurement correct	______
EMT measurements correct	______
90° bends accurate	______
Tubing fastened securely	______
Workmanship	______
Compliance to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
Eye protection
Hacksaw
½-inch conduit bender
20 feet of ½-inch EMT
Two 4-inch square outlet boxes with mounting screws
Space to install 20 feet of tubing with three 90-degree bends and a 4-inch square box at each end
Four ½-inch one-hole straps, or other supports
EMT couplings and connectors, setscrew or raintight

B. Procedure

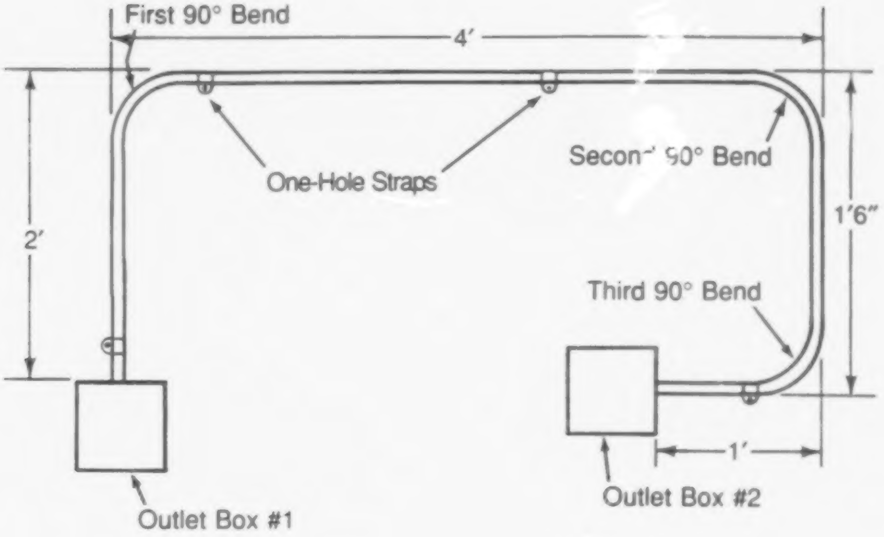
☐ 1. Observe safety rules throughout this procedure.

☐ 2. Check out proper tools and materials.

Job Sheet 5

☐ 3. Mount the two outlet boxes as shown in Figure 1.

Figure 1


First 90° Bend
4′
One-Hole Straps
Second 90° Bend
2′
1′6″
Third 90° Bend
1′
Outlet Box #2
Outlet Box #1

☐ 4. Open knockout holes only where needed for tubing connectors.

☐ 5. Install one EMT connector in each outlet box.

☐ 6. Measure distance and tubing for first 90-degree bend shown in Figure 1.

☐ 7. Make bend.

☐ 8. Measure tubing for second 90-degree bend.

☐ 9. Make bend.

☐ 10. Install and fasten tubing as shown in Figure 1.

Note: Refer to *NEC* Article 348-12 regarding straps.

☐ 11. Measure distance and tubing for third 90-degree bend.

Job Sheet 5

☐ 12. Bend tubing and install.

Note: If necessary, cut tubing to fit space. Be sure to wear eye protection when using hacksaw.

☐ 13. Return equipment and materials to proper storage.

☐ 14. Clean the work area.

Evaluator's comments: ____________________

____

____

Tools and Equipment
Unit 2

Job Sheet 6 — Bend a Three-Point Saddle on One-Half-Inch EMT

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Conduit saddle proper height	______
Center of saddle directly over obstruction	______
Bends accurate	______
Workmanship	______
Compliance to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

½-inch EMT bender
10 feet of ½-inch EMT
Pouch tools
2-inch O.D. pipe
2-inch pipe straps
Two 1900 boxes
Two ½" connectors
Two ½" one hole straps
Eight #10 × 1" SMS
Eye protection

B. Procedure

☐ 1. Observe safety rules throughout this procedure.

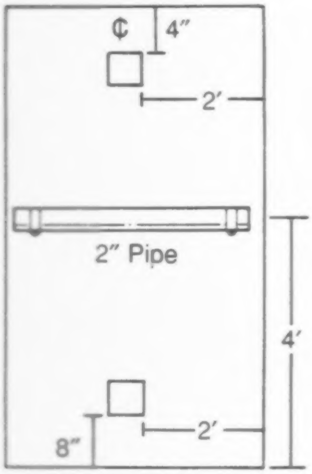
☐ 2. Check out proper tools and materials.

Job Sheet 6

☐ 3. Put on eye protection.

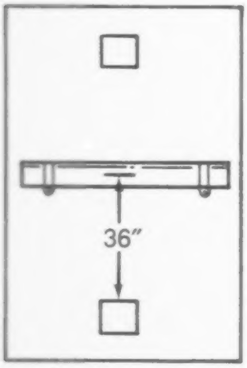
☐ 4. Mount the 2″ pipe in the center of a 4′ × 8′ sheet of plywood, then mount the two 1900 boxes as shown in Figure 1.

Figure 1



☐ 5. Measure from the bottom 1900 box to the center of the obstruction.

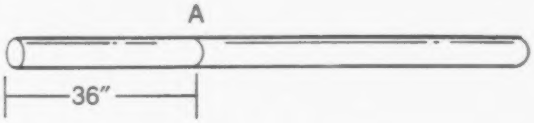
Figure 2



Job Sheet 6

☐ 6. Mark this measurement (A) on the ½" EMT.

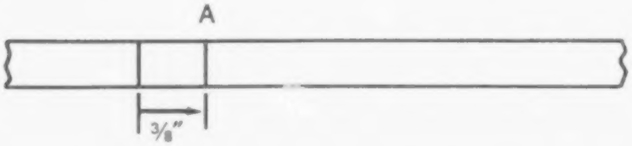
Figure 3



☐ 7. Measure the height of the obstruction. Move mark "A" ahead 3⁄16 of an inch for each inch of obstruction height. This becomes the center of the saddle.

Note: The obstruction is 2" high $\left(\frac{3}{16} \times 2 = \frac{6}{16} = \frac{3}{8}\right)$, so mark "A" is moved ahead ⅜".

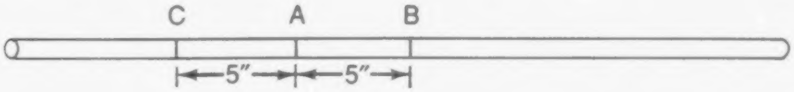
Figure 4



☐ 8. For each inch of obstruction height, multiply that amount by 2½. This will give you distance "L" between marks "A" and "B" and between marks "A" and "C". Calculate distance "L" and mark "B" and "C" on EMT.

Note: 2½ is a constant. In this case, the height is 2" (2 × 2½ = 5), so distance "L" will be 5".

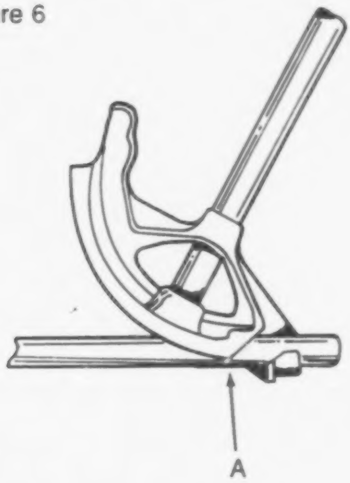
Figure 5



Job Sheet 6

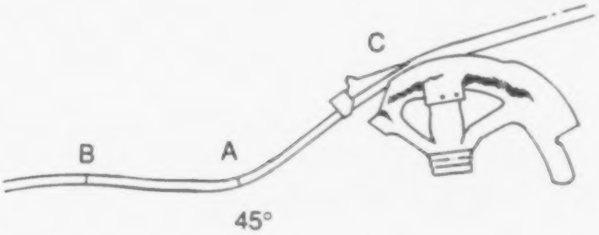
☐ 9. Place the bender rim notch or teardrop on mark "A" and pull to 45°.

Figure 6



☐ 10. Align mark "B" with the arrow on the bender and pull to 22½°. Repeat this by making a 22½° bend with mark "C" also at the arrow.

Figure 7



☐ 11. Install the conduit between the 1900 boxes.

Job Sheet 6

☐ 12. Return equipment and materials to proper storage.

☐ 13. Clean the work area.

Evaluator's comments: ____

____

____

Tools and Equipment
Unit 2

Job Sheet 7 — Bend a Four-Point Saddle on One-Half-Inch EMT

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Pipe measurements correct	______
Bends match	______
Workmanship	______
Compliance to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

½-inch EMT bender
10 feet of ½-inch EMT
Measuring tape
2″ × 4″ beam to be saddled
Eye protection

B. Procedure

☐ 1. Observe safety rules throughout this procedure.

☐ 2. Check out proper tools and materials.

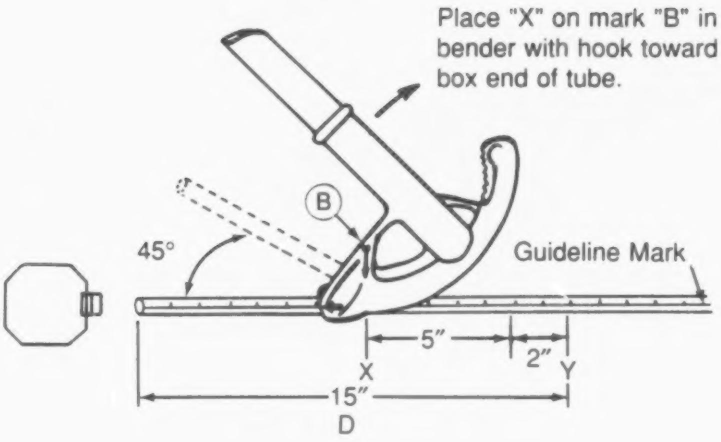
☐ 3. Put on eye protection.

☐ 4. Make a 4-inch offset bend (two 45° angles).

Note: Half the height of the offset (2 inches) plus 5 inches for ½-inch conduit equals 7-inches.

Job Sheet 7

Figure 1

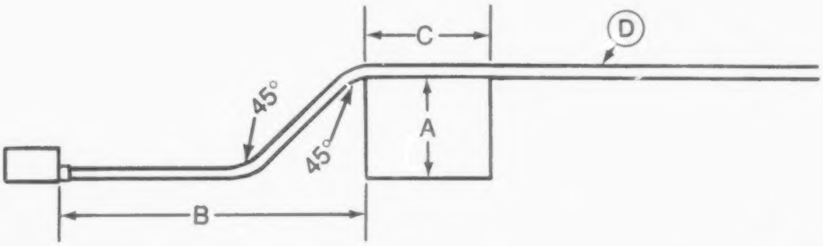

Place "X" on mark "B" in bender with hook toward box end of tube.
B
45°
Guideline Mark
5″
2″
X
Y
15″
D

Used with permission of Republic Steel Corporation.

☐ 5. Lay offset across beam to be saddled, and mark tubing at point D shown in Figure 2.

Figure 2

A = Height of Offset
B = Distance from Box to Offset
C = Width of Beam
D = Mark on Tube

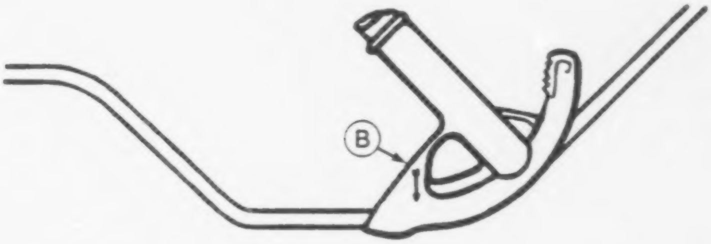


Used with permission of Republic Steel Corporation.

Job Sheet 7

☐ 6. Place tubing in bender, with bender point "B" at mark D. and bender hook toward finished part of offset.

Figure 3



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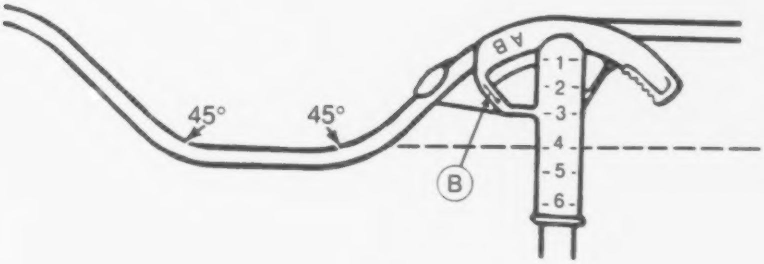
☐ 7. Make a 45-degree bend, and remove bender.

☐ 8. Complete this leg of saddle by sighting along edge of tubing to the 4-inch mark on bender as shown in Figure 4; mark tubing at 4-inch mark.

Figure 4



Used with permission of Republic Steel Corporation.

☐ 9. Remove bender, and place on tubing with bender point "B" at 4-inch mark.

☐ 10. Make a 45-degree bend, and remove bender.

Job Sheet 7

☐ 11. Place saddle over beam.

☐ 12. Return equipment and materials to proper storage.

☐ 13. Clean the work area.

Evaluator's comments: ______________________________

____

____

Tools and Equipment
Unit 2

Job Sheet 8 — Cut, Ream, Offset, and Install Connectors on One-Half-Inch PVC

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Measured pipe correctly	______
Placed bends at correct points	______
45° bends obtained	______
Workmanship	______
Compliance to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

10 feet of ½-inch EMT
Hacksaw
PVC bender
Skinning knife or other reaming tool
Two ½-inch PVC connectors
PVC cement
Eye protection
Measuring tape
Marking pencil

B. Procedure

☐ 1. Observe safety rules throughout this procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Put on eye protection.

Job Sheet 8

☐ 4. Measure and mark a 24-inch segment of PVC.

☐ 5. Cut off the 24-inch piece. using a hacksaw.

Note: PVC is soft enough to cut with a wood handsaw without damaging the saw.

☐ 6. Using a knife or reaming tool, remove burrs from inside and outside of cut conduit.

Note: Cleaner must be used if conduit has dirt or oil on it.

☐ 7. Using PVC bender, bend two box offsets.

☐ 8. Install PVC connector on one end of cleaned piece of PVC.

- Apply PVC cement to **conduit** (male end of the splice) **only**.

  Note: Close PVC cement container immediately after use. When PVC cement is applied to the female end of a splice, the cement is forced back into the conduit interior. When hard, it can damage insulation on wire and make pulling much more difficult.

- Quickly insert conduit into connector; twist the coupling one-quarter to one-half turn; let set for sixty seconds.

☐ 9. Repeat step 8 for other end of conduit.

☐ 10. Return equipment and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's comments: ____

____

____

Service
Unit 3

Objective Sheet

Unit Objective

After completing this unit, the student should be able to install 100 ampere service and determine switch gear, service entrance, drop clearances, laterals, and emergency standby systems. The student should demonstrate these competencies by completing the job sheets, and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to service with their correct definitions.
2. Complete statements concerning *NEC* requirements for drop clearance and laterals.
3. Select true statements concerning switch boards and disconnects.
4. Match *NEC* exceptions for overcurrent protection devices with their correct statements.
5. Complete statements concerning grounding electrodes and ground fault.
6. Select true statements concerning service entrance devices.
7. Complete statements concerning emergency and standby systems.
8. State the procedure for balancing loads.
9. Install an overhead raceway with service entrance conductors to a meter base. (Job Sheet 1)
10. Connect a meter base assembly to a load center or panel. (Job Sheet 2)

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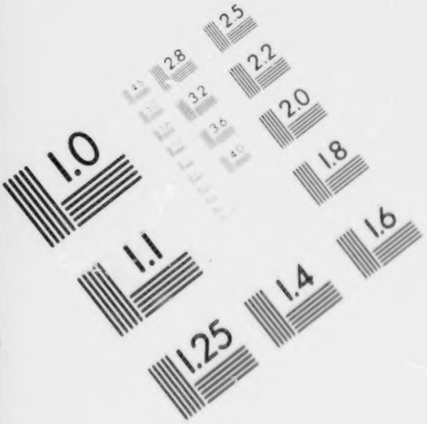
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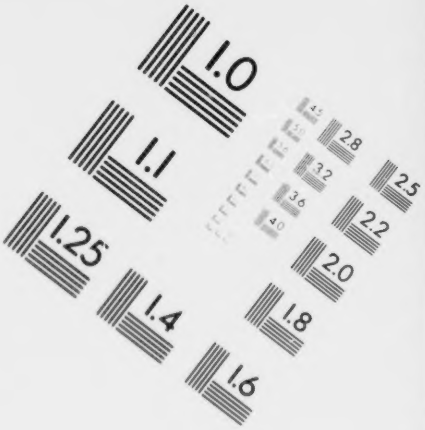
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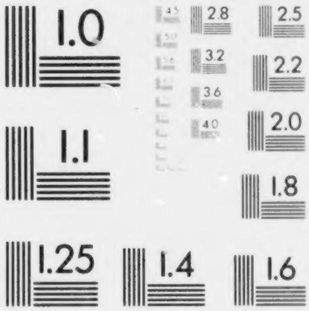
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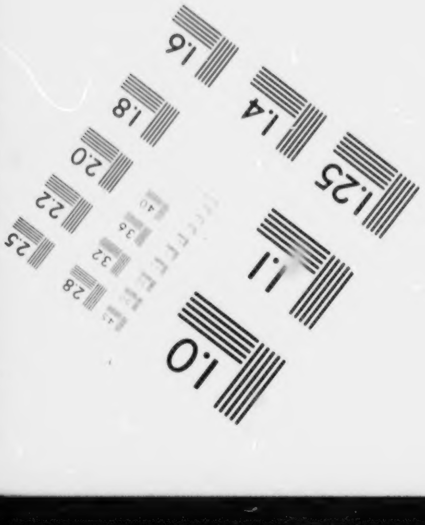
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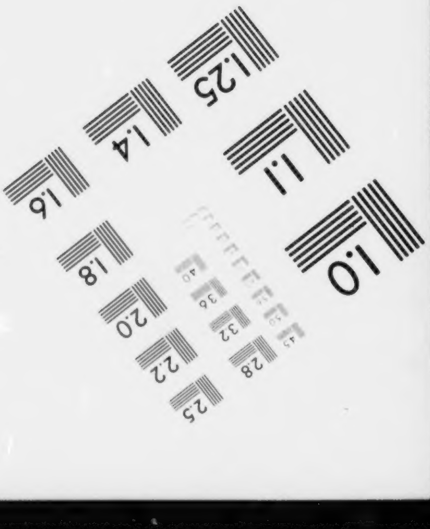
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Service
Unit 3

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.

2. Review Teaching Suggestions section that follows. Plan for classroom activities.

3. Plan for students with special needs.

4. Make transparencies from the transparency masters included with this unit. These appear in the teacher edition only and are designed to be used with the following objectives:

   TM 1—Potential Transformer (Objective 6)
   TM 2—Current Transformer (Objective 6)
   TM 3—Three-Phase Meter Base Assembly (Objective 7)

5. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.

6. Develop teaching plan. Adjust for different learning styles.

7. Make copies of Unit Evaluation Form.

Delivery and Application

8. Provide students with unit of instruction.

9. Discuss unit and specific objectives.

10. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.

11. Discuss the job sheets. Review criteria for evaluation of these activities.

Suggested Activities

Evaluation

12. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

13. Make copies of the written test. Add or modify test items as needed.

14. Give written test.

15. Record job sheet ratings and written test scores on the Unit Evaluation Form. Add any additional assignments or supplemental activities that should be part of the unit evaluation.

16. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Invite a local power company representative to discuss the uses of emergency and standby equipment and *NEC* regulations dealing with services. Have students practice looking up pertinent *NEC* articles. Skill areas: **listening**, and **reading**.

2. Take students on a field trip to a power company. Encourage students to ask questions regarding the plant operation. Skill area: **oral communication**.

3. Have a supply house representative demonstrate the different devices for services. Skill area: **listening**.

Resources Used in Developing This Unit

1. Kaltwasser, Stan and Gary Flowers. *Commercial and Industrial Wiring*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1988.

2. *National Electrical Code 1993*. Quincy, MA: National Fire Protection Association, 1992.

3. Stallcup, James G. *Designing Electrical Systems Based on the 1990 NEC*. Alsip, IL: American Technical Publishers, Inc., 1990.

Suggested Activities

Suggested Supplemental Resources

1. Croft, Terrell and Wilford I. Summers. *American Electrician's Handbook*, 11th Ed. New York: McGraw-Hill Book Company, 1987.
2. Earley, Mark W., John M. Caloggero and Richard H. Murray. *NEC Handbook 1993*. Quincy, MA: National Fire Protection Association, 1992.
3. O'Riley, Ronald P. *Illustrated Changes in the 1993 National Electrical Code*. Albany, NY: Delmar Publishers, Inc., 1993.

Instructions for Evaluating Student Performance

Job Sheets—Be sure the student understands the criteria on which the evaluation is based. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher edition or student manual. Then observe the student performing the procedure. Rate both process and product.

> Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.
>
> Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. Complete the rating by assigning a point value to each criterion and by converting the point total to a percentage for grading. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) which best fits your program needs.

Option A

4 - Skilled—Can perform job with no additional training.
3 - Moderately skilled—Has performed job during training program; limited additional training may be required.
2 - Limited skill—Has performed job during training program; additional training is required to develop skill.
1 - Unskilled—Is familiar with process, but is unable to perform job.

Option B

Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

Service
Unit 3

Answers to Written Test

1.

a.	8	e.	1	i.	10
b.	6	f.	5	j.	12
c.	2	g.	9	k.	3
d.	4	h.	11	l.	7

2.
   a. Overhead, underground (lateral)
   b. Grade
   c. #8, #6
   d. 8 feet
   e. 3 feet, 300
   f. 18
   g. 600V
   h. #8, #6

3. a

4.
   a. 3
   b. 2
   c. 1
   d. 4

5.
   a. Metal, steel, 20 feet, ring
   b. Is

6. b

7.
   a. Generator, battery, hospitals
   b. Automatic transfer switch

8. When balancing loads on panels, transformers, and switching equipment, an amprobe should be used to determine amperage on each circuit.

Service
Unit 3

Written Test

Name ______________________________ Score ______________

1. Match the terms on the right with their correct definitions.

_____a. Potential transformer

_____b. System or circuit conductor that is intentionally grounded

_____c. Device used for breaking a circuit which may be fused or unfused

_____d. Any good conductor that is connected to a common chassis with zero relative voltage

_____e. Current transformer

_____f. Connected to the earth or to some conducting body that serves in place of the earth

_____g. Where power is metered or is first attached to the structure

_____h. Main control panel where voltage and current are distributed to different locations

_____i. Power conductors coming into building from power company

_____j. Large single panel or assembly of panels on which are mounted, on the face or back or both, switches, overcurrent, and other protective devices, busses, and usually instruments; generally accessbile from the rear as well as the front and intended to be installed in a cabinet

1. CT
2. Disconnects
3. Equipment grounding conductor
4. Ground
5. Grounded
6. Grounded conductor
7. Grounding electrode conductor
8. PT
9. Service
10. Service drop
11. Service panel
12. Switch board

Written Test

_____k. Conductor used to connect non-current carrying metal parts of equipment to the system-grounded conductor or grounding-electrode conductor

_____l. Conductor used to connect grounding electrode to the equipment grounding conductor or to grounding conductor of circuit at service equipment or at source of separately derived system

2. Complete the following statements concerning *NEC* requirements for drop clearance and laterals.

   a. There are two basic types of services: _______________ and _______________.

   b. Overhead services must be a specific size and have a minimum clearance from the finished _______________.

   c. The smallest conductors that can be used on a service are _______________ copper and _______________ aluminum.

   d. Service drop conductors passing over a roof must be at least _______________ above the roof.

   e. Exception No. 2 allows service drops to pass _______________ feet above the roof when the roof has a slope of 4 inches in 12 inches and the voltage is not in excess of _______________ volts.

   f. Exception No. 3 allows the service drop to be attached to the service mast when the drop does not pass over 4 feet of roof and the mast is at least _______________ inches above the roof line.

   g. Service drop conductors rated at _______________ or less have minimum clearances.

   h. An underground service lateral must have a conductor size of at least _______________ copper or _______________ aluminum.

Written Test

3. Select true statements concerning switch boards and disconnects by placing an "X" in the blank preceding each true statement.

______a. A switch board is used for breaking the current or voltage from the meter base to the means of disconnection before being allowed to enter branch circuits.

______b. Service disconnects are readily accessible for breaking the power entering a building. Only one disconnect may be used on a service.

______c. Few service disconnects have overload protection. The disconnect must be large enough to carry the computed load it supplies.

4. Match the *NEC* exceptions for overcurrent protection devices on the right with their correct statements.

______a. Two to six CBs or fuses may serve as overcurrent protection devices.

______b. If not a standard size, the next higher standard size overcurrent protection device is used.

______c. An overcurrent protection device may be overfused to allow motors to attain running speed.

______d. An overcurrent protection device must be rated to carry locked-rotor current of fire pump motors.

1. Exception No. 1
2. Exception No. 2
3. Exception No. 3
4. Exception No. 4

5. Complete the following statements concerning grounding electrodes and ground fault by circling the correct words.

a. There are four types of electrode grounding systems used in electrical trades. They include (aluminum, metal) water pipe, building (steel, iron), reinforcing rod (15 feet, 20 feet) minimum length, and ground (rod, ring).

b. A ground (is, is not) required if the power company's secondary system is not efficiently grounded.

Written Test

6. Select true statements concerning service entrance devices by placing an "X" in the blank preceding each true statement.

    ______a. A current transformer (CT) steps the voltage down so voltage measuring devices may be used.

    ______b. Conductor sizes of 1/0 or larger comprising each phase to neutral will be permitted to be connected in parallel. This means two conductors are used as one.

    ______c. A potential transformer (PT) is a doughnut type device used in measuring current. These are used in metering large services.

7. Complete the following statements concerning emergency and standby systems.

    a. Separate, derived systems such as a ________________ or ________________ backup are used when the incoming voltage from the power company is interrupted or cut off. These systems are used in __________________, factories, and stores where electricity is a must.

    b. An ___________________ ___________________ ___________________ senses a voltage loss and automatically switches a system to emergency power.

8. State the procedure for balancing loads.

    ____

    ____

*Permission to duplicate this test is granted.

Service
Unit 3

Unit Evaluation Form

Student Name ____________________ Unit Rating __________

Job Sheet 1—Install an Overhead Raceway With Service Entrance Conductors to a Meter Base Rating ______

Comments: ______________________________

____

Job Sheet 2—Connect a Meter Base Assembly to a Load Center or Panel Rating ______

Comments: ______________________________

____

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ______________________________

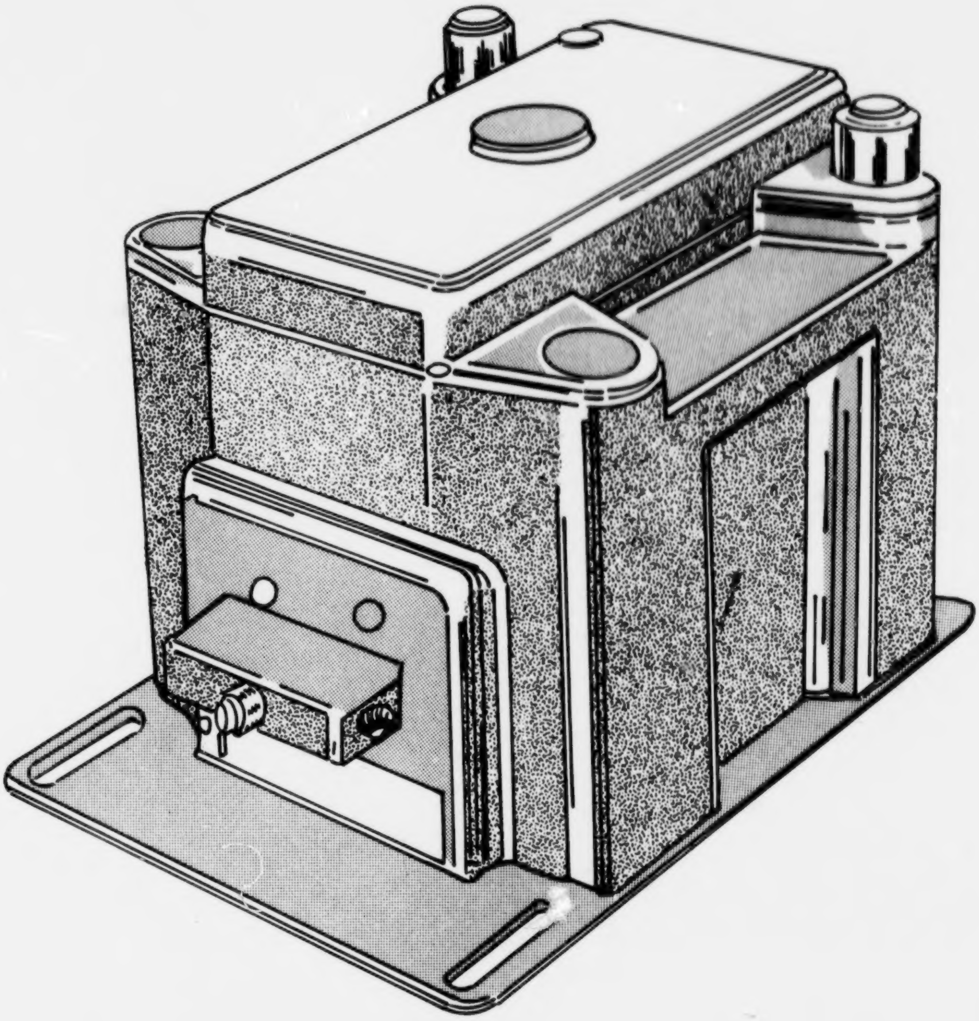
____

Teacher Signature ____________________ Date __________

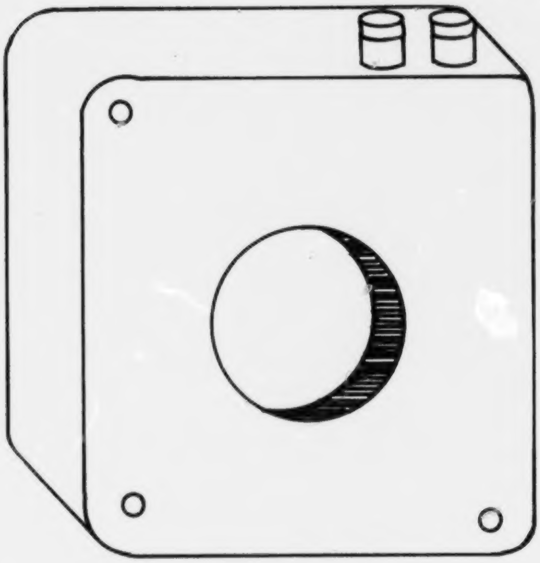
Student Signature ____________________ Date __________

***Permission to duplicate this form is granted.**

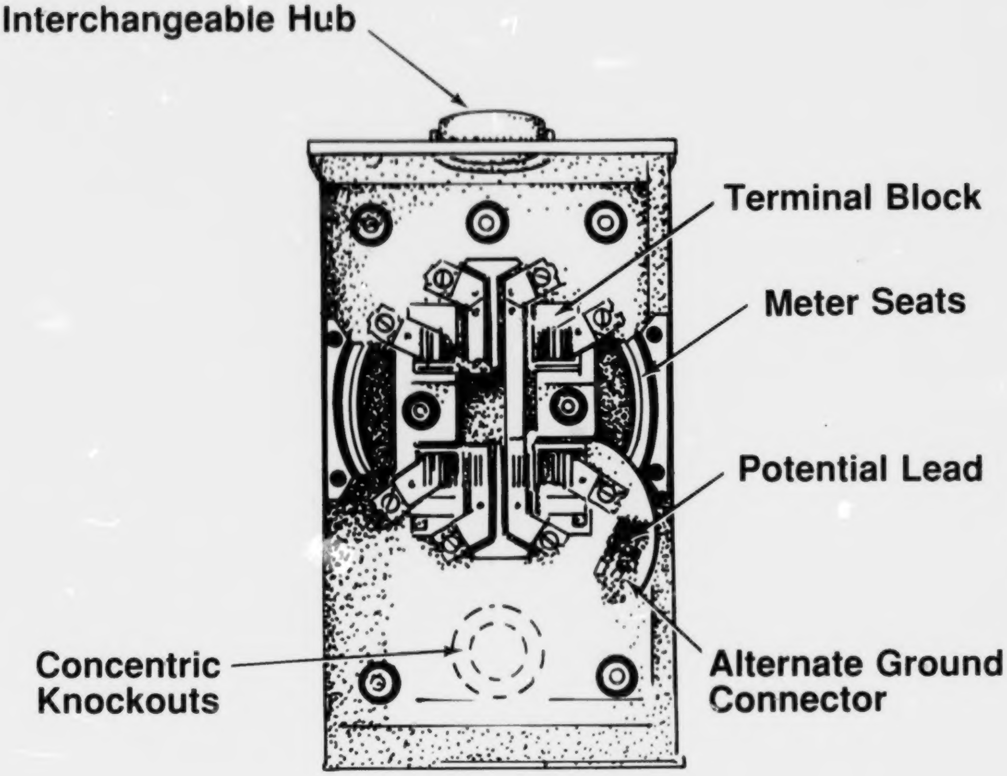
Potential Transformer



Current Transformer



Three-Phase Meter Base Assembly


Interchangeable Hub
Terminal Block
Meter Seats
Potential Lead
Concentric Knockouts
Alternate Ground Connector

Service
Unit 3

Information Sheet

1. **Terms and definitions**

   a. **CT** — Current transformer

   b. **Disconnects** — Devices used for breaking a circuit which may be fused or unfused

   c. **Equipment grounding conductor** — Conductor used to connect non-current carrying metal parts of equipment to the system-grounded conductor or grounding-electrode conductor

   d. **Ground** — Any good conductor that is connected to a common chassis with zero relative voltage

   Note: Usually conductors are connected to the earth.

   e. **Grounded** — Connected to the earth or to some conducting body that serves in place of the earth

   f. **Grounded conductor** — System or circuit conductor that is intentionally grounded

   g. **Grounding-electrode conductor** — Conductor used to connect grounding electrode to the equipment grounding conductor or to grounding conductor of circuit at service equipment or at source of separately derived system

   h. **PT** — Potential transformer

   i. **Service** — Where power is metered or is first attached to the structure

   j. **Service drop** — Power conductors coming into building from power company

   k. **Service panel** — Main control panel where voltage and current are distributed to different locations

   Note: A service panel may also be referred to as a distribution panel or panelboard.

   l. **Switch board** — Large single panel, frame, or assembly of panels on which are mounted, on the face or back or both, switches, overcurrent, and other protective devices, busses, and usually instruments; generally accessible from the rear as well as the front and intended to be installed in a cabinet

Information Sheet

2. *NEC* requirements for drop clearance and laterals

a. There are two types of services used in the electrical trade: overhead and underground (lateral). Overhead services have different code requirements than underground.

b. Overhead services must be a specific size and have a minimum clearance from the finished grade.

c. The smallest conductors that can be used on a service are #8 copper and #6 aluminum. In special cases #12 hard-drawn copper may be used on branch or small equipment.

Note: Refer to *NEC* Article 230-23.

d. Clearances for service drops must comply with the *NEC*. Service drop conductors passing over a roof must be at least 8 feet above the roof.

Note: Refer to *NEC* Article 230-24.

e. There are two *NEC* exceptions which pertain to service drops.

- Exception No. 2 allows service drops to pass 3 feet above the roof when the roof has a slope of 4 inches in 12 inches and the voltage is not in excess of 300 volts. When voltage is in excess of 300 volts, an 8 foot clearance must be used.

  Note: Refer to *NEC* Article 230-24.

- Exception No. 3 allows the service drop to be attached to the service mast when the drop does not pass over 4 feet of roof and the mast is at least 18 inches above the roof line.

f. Service drop conductors rated at 600V or less have minimum clearances.

Note: Refer to *NEC* Article 230-24(b).

g. An underground service lateral must have a conductor size of at least #8 copper or #6 aluminum.

Note: Refer to *NEC* Article 230-31(b).

Information Sheet

3. **Switch boards and disconnects**

   a. A switch board is used for breaking the current or voltage from the meter base to the means of disconnection before being allowed to enter branch circuits.

   b. Service disconnects are readily accessible for breaking the power entering a building. More than one disconnect may be used on a service.

   Note: Refer to *NEC* Articles 230-71 and 230-72.

   c. All service disconnects have overload protection. The disconnect must be large enough to carry the computed load it supplies.

   Note: Refer to *NEC* Articles 230-79 and 230-90.

4. ***NEC* exceptions for overcurrent protection devices**

   Note: Overcurrent protection devices must not be greater than the load carrying capacity of the service entrance conductors. There are four exceptions to *NEC* Article 230-90 for overcurrent protection for services.

   a. Exception No. 1 — An overcurrent protection device may be overfused to allow motors to attain running speed.

   b. Exception No. 2 — If not a standard size, the next higher standard size overcurrent protection device is used.

   c. Exception No. 3 — Two to six CBs or fuses may serve as overcurrent protection devices.

   d. Exception No. 4 — An overcurrent protection device must be rated to carry locked-rotor current of fire pump motors.

5. **Grounding electrodes and ground fault**

   a. There are four types of electrode grounding systems used in electrical trades.

   Note: Refer to *NEC* Article 250-81.

   - Metal water pipe
   - Building steel
   - Reinforcing rod (20 feet minimum length)
   - Ground ring

   b. A ground is required if the power company's secondary system is not efficiently grounded.

   Note: Refer to *NEC* Article 250-23(b).

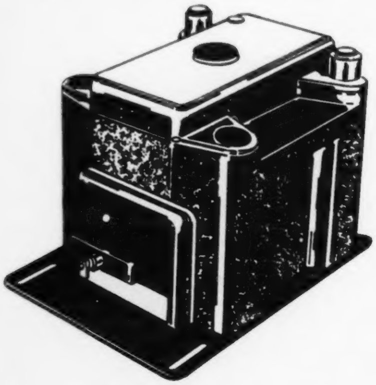
Information Sheet

6. Service entrance devices

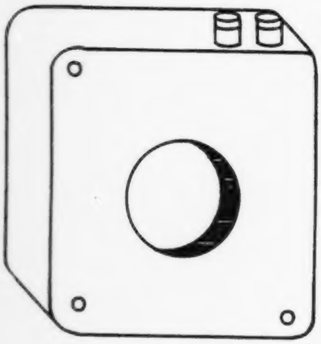
a. Conductor sizes of 1/0 or larger comprising each phase to neutral will be permitted to be connected in parallel. This means two conductors are used as one.

Note: Refer to *NEC* Article 310-4.

b. A potential transformer steps the voltage down so voltage measuring devices may be used.



c. A current transformer is a doughnut type device used in measuring current. An amprobe clamp-on ammeter is a current transformer. These are used in metering large services.



Information Sheet

7. **Emergency and standby systems**

   Note: Refer to *NEC* Article 700.

   a. Separate, derived systems such as a generator or battery backup are used when the incoming voltage from the power company is interrupted or cut off. These systems are used in hospitals, factories, and stores where electricity is a must.

   b. An automatic transfer switch senses a voltage loss and automatically switches a system to emergency power.

8. **Balancing loads** — When balancing loads on panels, transformers, and switching equipment, an amprobe should be used to determine amperage on each circuit. The sum of the loads on each phase should be close to equal value.

Service
Unit 3

Job Sheet 1—Install an Overhead Raceway With Service Entrance Conductors to a Meter Base

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation Criteria	Rating
Practiced safety rules throughout procedure	_____
Pipe installed correctly	_____
Service head properly connected	_____
Marked conductors properly	_____
Correct length on conductors	_____
Mounted correctly	_____
Workmanship	_____
Compliance to *NEC*	_____

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Flat blade screwdriver
Lineman's pliers
Hammer
Knife
Hacksaw
Folding rule with sliding scale
3ϕ meter base
Service entrance cap (1½″ clamp-on type)
Three feet of 1½″ rigid metal conduit (threaded on one end)
Twelve feet of #2 copper TW (two 6′ pieces)
Six feet of #4 copper
Eye protection

Job Sheet 1

B. Procedure

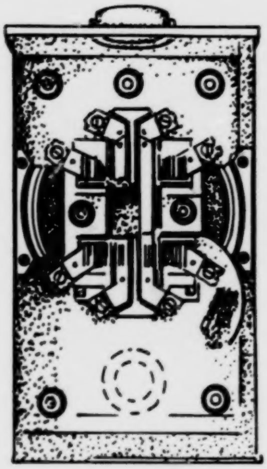
☐ 1. Observe safety rules throughout this procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Put on eye protection.

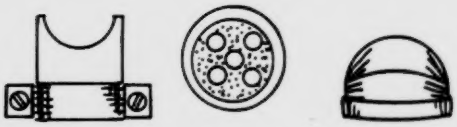
☐ 4. Screw threaded end of raceway into hub.

Figure 1



☐ 5. Remove cover and separator from weatherhead.

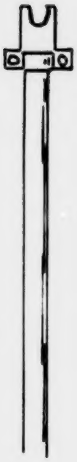
Figure 2



Job Sheet 1

☐ 6. Clamp weatherhead base onto the end of the service raceway.

Figure 3



☐ 7. Install conductors in the raceway.

Note: Start at weatherhead end.

☐ 8. Connect the grounded conductor to the grounding lug.

Note: When possible, leave the grounded conductor long enough to connect to the disconnect equipment grounding bar.

☐ 9. Remove 1" to 1½" of insulation from the ungrounded conductors and connect to the line lugs.

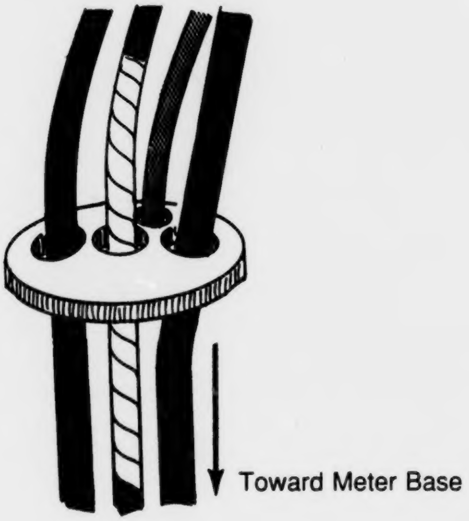
☐ 10. Knock out four outline holes in the entrance cap separator.

☐ 11. Put the grounded conductor through the center hole.

Job Sheet 1

☐ 12. Put the ungrounded conductors through the side holes

Figure 4



☐ 13. Gently start forming conductors so the separator will fit back into the base.

Note: Care must be taken while you are bending the curvature in the conductors to prevent damage to the plastic conductor separator.

☐ 14. Replace the service entrance cap cover.

☐ 15. Return tools and materials to proper storage.

☐ 16. Clean the work area.

Evaluator's comments: ______________________________

____

____

Service
Unit 3

Job Sheet 2—Connect a Meter Base Assembly to a Load Center or Panel

Name ____________________ Attempt Number ________

Date ____________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Panel mounted correctly	______
Nipple installed properly	______
Conductors terminated	______
Workmanship	______
Compliance to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Screwdriver
Lineman's pliers
Hammer
Knife
Level
Rule
Awl
Meter base assembly from Job Sheet 1
Two 1¼″ insulating bushings
Four 1¼″ locknuts
One 1¼″ reamed nipple long enough to connect meter base to distribution panel (Nipple, bushings, and locknuts may be larger than 1¼″ if conductor size or necessity mandates.)
#4 copper (1 piece)
#2 TW copper (3 pieces)
Eight 1″ #12 metal tapping screws
One 1½″ rigid conduit strap
2′ × 4′ mock-up wall or roughed in residential dwelling
Eye protection
One 100-amp 3-phase 3-wire SN load center

Job Sheet 2

B. Procedure

☐ 1. Observe safety rules throughout this procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Put on eye protection.

☐ 4. Mount the load center between studs with metal tapping screws.

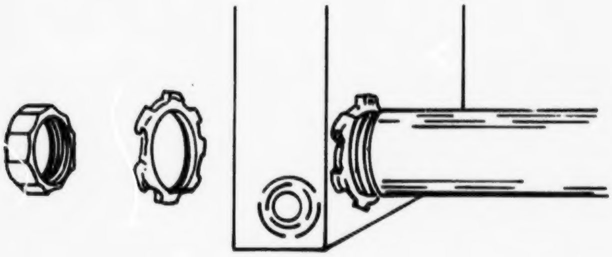
Note: Panel height should be adjusted so that knockouts will line up with meter base between 5′ and 6′. The utility company will give you their recommended height.

☐ 5. Remove the load center knockout that will align with the meter base at the correct height.

☐ 6. Install a nipple in the opening with a locknut on the back side of the load center and a locknut and bushing on the inside.

Note: Be sure that locknuts are installed tightly with their teeth into the metal. Also be sure to check local codes on bonding.

Figure 1



☐ 7. Remove the appropriate knockout from the meter base.

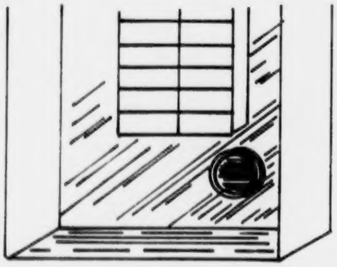
☐ 8. Put the back-up locknut for the metal base on the nipple.

Job Sheet 2

☐ 9. Place the nipple through the meter base knockout and secure it loosely with one screw.

Note: Cut off excess nipple; leave only what is needed for the locknut and bushing.

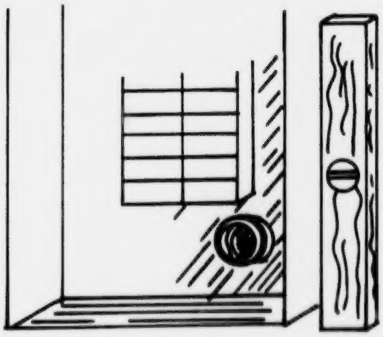
Figure 2



☐ 10. Install the internal locknut and bushing.

☐ 11. Place level on side of meter base and secure the base with mounting screws when leveled.

Figure 3



☐ 12. Put level on service raceway and secure the raceway with the strap when leveled.

Job Sheet 2

☐ 13. Install a grounded conductor in a nipple and connect to the meter base and load center grounded lugs.

Note: Make all bends in conductors as square as possible while maintaining a radius equal to at least five times the diameter. Make sure you stay as far as possible from load and line lugs in your routing of the grounded conductors.

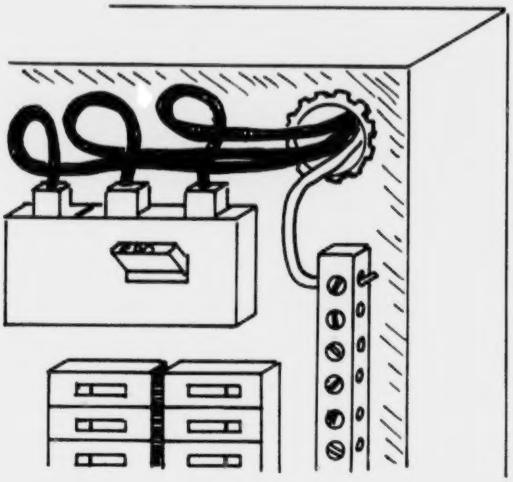
☐ 14. Install the ungrounded conductors in the nipple.

☐ 15. Strip about 1½" insulation from each of the ungrounded conductors, form them, and connect them to meter load lugs.

☐ 16. Form ungrounded conductors in load center.

☐ 17. Cut off excess and connect to the load center line lugs.

Figure 4



Note: The service system is still without a grounding electrode conductor. This conductor can originate at the load center or in the meter base. It can terminate at a cold water pipe or made electrode.

☐ 18. Return tools and materials to proper storage.

☐ 19. Clean the work area.

Evaluator's comments: ______________________________

____

____

Transformers
Unit 4

Objective Sheet

Unit Objective

After completing this unit, the student should be able to refer to the *NEC* to determine transformer locations and to identify specific transformer requirements. The student should demonstrate these competencies by completing the assignment sheets and job sheets, and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to transformers with their correct definitions.
2. List basic types of transformers.
3. Draw diagrams of the most commonly used voltage systems.
4. Select true statements concerning *NEC* requirements for dry type transformers.
5. Complete statements concerning *NEC* requirements for oil-filled transformers.
6. Select true statements concerning *NEC* requirements for askarel-filled transformers.
7. State the function of a buck and boost transformer.
8. Match *NEC* articles with their correct transformer locations.
9. Match *NEC* articles with the correct installation and termination of transformers.
10. Locate and list two exceptions on transformer room construction for dry type transformers. (Assignment Sheet 1)
11. Locate and list two exceptions concerning oil-insulated transformers. (Assignment Sheet 2)
12. Draw a three-phase wye-delta transformer. (Assignment Sheet 3)
13. Convert amperes to KVA on a three-phase system. (Assignment Sheet 4)
14. Test transformer turn ratios. (Job Sheet 1)
15. Test transformer insulation resistance. (Job Sheet 2)
16. Connect transformer primary and secondary windings in a delta-wye configuration. (Job Sheet 3)

Transformers
Unit 4

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.

2. Review Teaching Suggestions section that follows. Plan for classroom activities.

3. Plan for students with special needs.

4. Make transparency from the transparency master included with this unit. This appears in the teacher edition only and is designed to be used with the following objective:

   TM 1—Basic Types of Transformers (Objective 2)

5. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.

6. Develop teaching plan. Adjust for different learning styles.

7. Make copies of Unit Evaluation Form.

Delivery and Application

8. Provide students with unit of instruction.

9. Discuss unit and specific objectives.

10. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.

11. Discuss the assignment and job sheets. Review criteria for evaluation of these activities.

Suggested Activities

Evaluation

12. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

13. Make copies of the written test. Add or modify test items as needed.

14. Give written test.

15. Record assignment sheet ratings, job sheet ratings, and written test scores on the Unit Evaluation Form. Add any additional assignments or supplemental activities that should be part of the unit evaluation.

16. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Invite a representative from a transformer winding shop to class to discuss transformer maintenance. Skill area: **listening**.

2. Have students refer to the *NEC* to locate specific *NEC* requirements pertaining to transformers. Have students list the *NEC* article number and briefly describe the indicated requirements. Skill areas: **reading** and **writing**.

Resources Used in Developing This Unit

1. Kaltwasser, Stan and Gary Flowers. *Commercial and Industrial Wiring*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1988.

2. *National Electrical Code 1993*. Quincy, MA: National Fire Protection Association, 1992.

3. Stallcup, James G. *Designing Electrical Systems Based on the 1990 NEC*. Alsip, IL: American Technical Publishers, Inc., 1990.

4. Turner, J. Howard. *Understanding Electricity and Electrical Terms*. Athens, GA: American Association for Vocational Instructional Materials, 1974.

Suggested Activities

Suggested Supplemental Resources

1. Croft, Terrell and Wilford I. Summers. *American Electrician's Handbook*. 11th Ed. New York: McGraw-Hill Book Company, 1987.

2. Earley, Mark W., John M. Caloggero and Richard H. Murray. *NEC Handbook 1993*. Quincy, MA: National Fire Protection Association, 1992.

3. O'Riley, Ronald P. *Illustrated Changes in the 1993 National Electrical Code*. Albany, NY: Delmar Publishers, Inc., 1993.

4. *Transformer Maintenance*. NUS Training Corporation, 1350 Piccard Drive, Rockville, MD 20850. (Film)

Instructions for Evaluating Student Performance

Assignment Sheets—Be sure the student understands the criteria on which the evaluation is based. Assign a point value to each criterion and convert the total points to a percentage for grading.

Job Sheets—Be sure the student understands the criteria on which the evaluation is based. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher or student edition. Then observe the student performing the procedure. Rate both process and product.

> Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.
>
> Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. Complete the rating by assigning a point value to each criterion and by converting the point total to a percentage for grading. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Suggested Activities

Sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) which best fits your program needs.

Option A

4 - Skilled—Can perform job with no additional training.
3 - Moderately skilled—Has performed job during training program; limited additional training may be required.
2 - Limited skill—Has performed job during training program; additional training is required to develop skill.
1 - Unskilled—Is familiar with process, but is unable to perform job.

Option B

Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

Transformers
Unit 4

Answers to Assignment Sheets

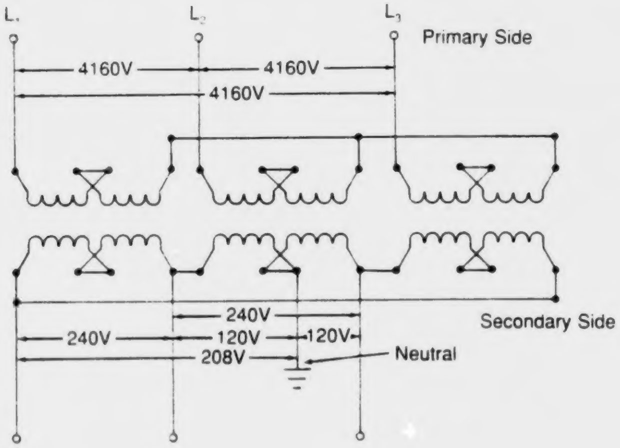
Assignment Sheet 1

A. *NEC* Article 450-21(b), Exception No. 1
B. *NEC* Article 450-21(b), Exception No. 2

Assignment Sheet 2

A.-B. *NEC* Article 450-26, Exceptions No. 1 through No. 5 (any two)

Assignment Sheet 3


L₁
L₂
L₃
Primary Side
4160V
4160V
4160V
240V
240V
120V
120V
208V
Secondary Side
Neutral

Assignment Sheet 4

A. 50
B. 100
C. 200
D. 500

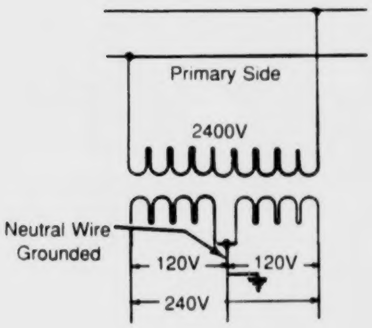
Transformers
Unit 4

Answers to Written Test

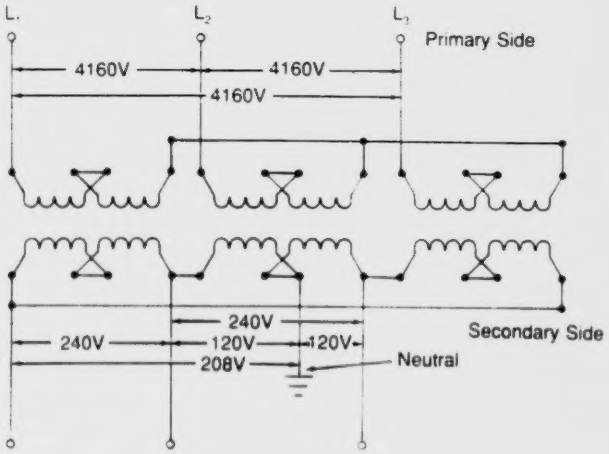
1. a. 2
   b. 3
   c. 4
   d. 1

2. a. Dry type
   b. Oil-filled
   c. Askarel-filled

3. a. Single phase transformer


Primary Side
2400V
Neutral Wire Grounded
120V
120V
240V

b. Three phase transformer


L.
L₂
L₃
Primary Side
4160V
4160V
4160V
240V
240V
120V
120V
208V
Neutral
Secondary Side

4. a, b

5. a. Vault
   b. Indoors
   c. Outdoors

6. a, b, d

7. It is used to increase or decrease voltage.

8. a. 4
   b. 1
   c. 6
   d. 3
   e. 2
   f. 5

9. a. 1
   b. 3
   c. 2

Transformers
Unit 4

Written Test

Name ______________________________ Score ______________

1. Match the terms on the right with their correct definitions.

_____a. A transformer that increases or decreases voltage

_____b. Insulates the primary circuit from the secondary circuit, but frequently with no voltage change

_____c. Area in which transformers are installed for safety protection, usually constructed with concrete and fire-retardant doors

_____d. The temperature in the area where the transformer is to be located

1. Ambient temperature
2. Buck and boost transformer
3. Isolating transformer
4. Transformer vault

2. List three basic types of transformers.

a. ______________________________

b. ______________________________

c. ______________________________

Written Test

3. Draw diagrams of the two most commonly used voltage systems.

   a. Single phase transformer

   b. Three phase transformer

Written Test

4. Select true statements concerning *NEC* requirements for dry type transformers by placing an "X" in the blank preceding each true statement.

______a. Dry type transformers installed indoors rated at 112.5 KVA or less must have a fire resistant, heat insulating barrier between transformer and combustible materials.

______b. Dry type transformers require a 12" separation or barrier if they are enclosed and are rated less than 112.5 KVA and will operate at 600V or less.

______c. Dry type transformers rated over 15,000 volts must be installed in a vault.

5. Complete the following statements concerning *NEC* requirements for oil-filled transformers.

a. Oil-filled transformers can be installed indoors and outdoors. When mounted indoors, oil-filled transformers must be mounted in a ________________.

b. *NEC* Article 450-26 pertains to oil-insulated transformers which are installed ________________.

c. *NEC* Article 450-27 pertains to oil-insulated transformers which are installed ________________.

6. Select true statements concerning *NEC* requirements for askarel-filled transformers by placing an "X" in the blank preceding each true statement.

______a. Askarel-filled transformers are filled with a liquid called askarel which will not burn and is nonexplosive.

______b. Gases are produced as a result of arcing.

______c. A vent is not required if the transformer is under 115 KVA.

______d. *NEC* Article 450-25 pertains to askarel-insulated transformers installed indoors.

7. State the function of a buck and boost transformer.

____

____

Written Test

8. Match *NEC* articles on the right with their correct transformer locations.

______a. Ventilation openings

______b. Transformer vaults

______c. Storage in vaults

______d. Doorways

______e. Walls, roofs, and floors

______f. Water pipes and accessories

1. *NEC* Article 450-41
2. *NEC* Article 450-42
3. *NEC* Article 450-43
4. *NEC* Article 450-45
5. *NEC* Article 450-47
6. *NEC* Article 450-48

9. Match *NEC* articles on the right with the correct installation and termination of transformers.

______a. Mounting of transformers must comply with code on location, storage, and uses.

______b. Overcurrent protection may be installed on primary and secondary windings of transformers.

______c. Grounding of transformers

1. *NEC* Article 450-2
2. *NEC* Article 450-10
3. *NEC* Article 240-3

***Permission to duplicate this test is granted.**

Transformers
Unit 4

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Assignment Sheet 1—Locate and List Two Exceptions on Transformer Room Construction for Dry Type Transformers Rating ______

Comments: ____

____

Assignment Sheet 2—Locate and List Two Exceptions Concerning Oil-Insulated Transformers Rating ______

Comments: ____

____

Assignment Sheet 3—Draw a Three-Phase Wye-Delta Transformer Rating ______

Comments: ____

____

Assignment Sheet 4—Convert Amperes to KVA on a Three-Phase System Rating ______

Comments: ____

____

Job Sheet 1—Test Transformer Turn Ratios Rating ______

Comments: ____

____

Job Sheet 2—Test Transformer Insulation Resistance Rating ______

Comments: ____

____

Job Sheet 3—Connect Transformer Primary and Secondary Windings in a Delta-Wye Configuration Rating ______

Comments: ____

____

Unit Evaluation Form

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ____

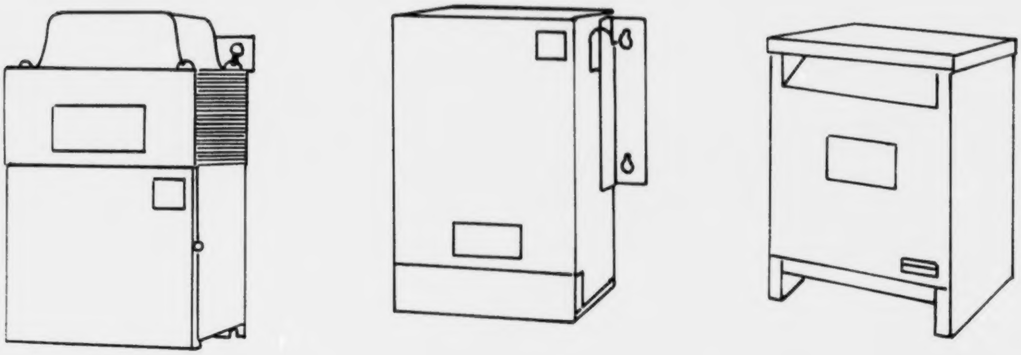
____

Teacher Signature ________________________________ Date ____________

Student Signature ________________________________ Date ____________

*Permission to duplicate this form is granted.**

Basic Types of Transformers

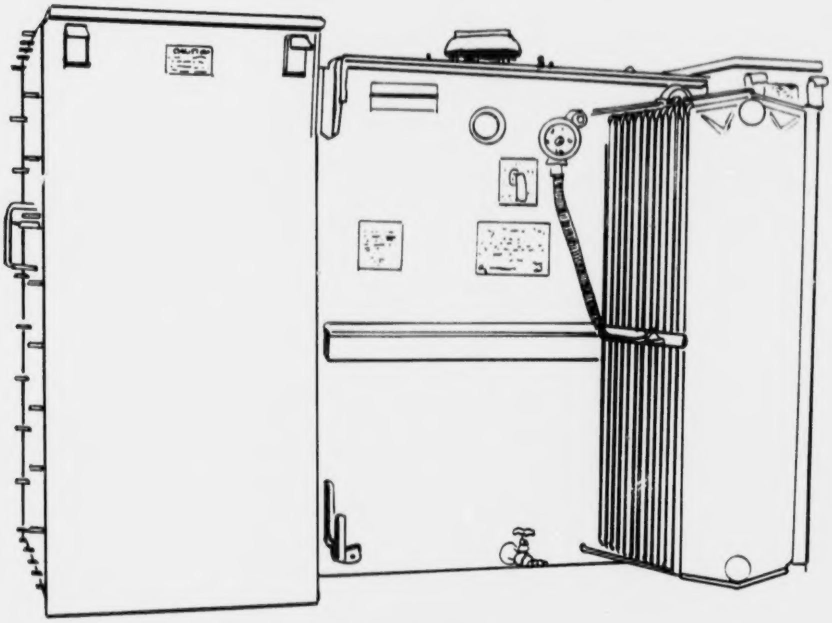


Indoor

Outdoor

Floor Mount

Dry Type



Oil Filled

Transformers
Unit 4

Information Sheet

1. **Terms and definitions**

   a. **Ambient temperature** — The temperature in the area where any electrical equipment is to be located

   Note: High temperatures will raise the insulation temperatures and shorten the life of the electrical equipment.

   b. **Buck and boost transformer** — A transformer that increases or decreases voltage

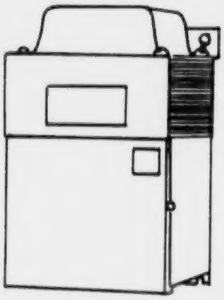
   c. **Isolating transformer** — Insulates the primary circuit from the secondary circuit, but frequently with no voltage change

   d. **Transformer vault** — Area in which transformers are installed for safety protection, usually constructed with concrete and fire-retardant doors

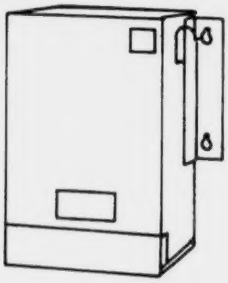
2. **Basic types of transformers**

   a. Dry type — Do not have their core and coils submerged in oil

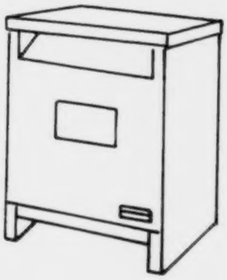
- Indoor



- Outdoor

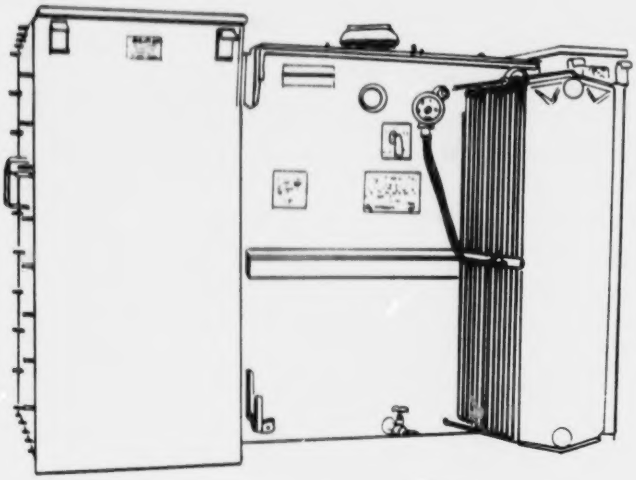


- Floor mount



Information Sheet

b. Oil-filled — Must have their core and coils submerged in oil

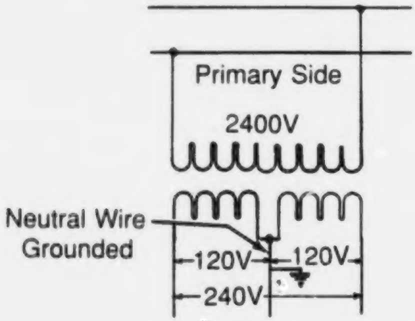


c. Askarel-filled — Filled with a liquid which produces gases from arcing

Note: Askarel-filled transformers are slowly being eliminated due to the presence of PCBs.

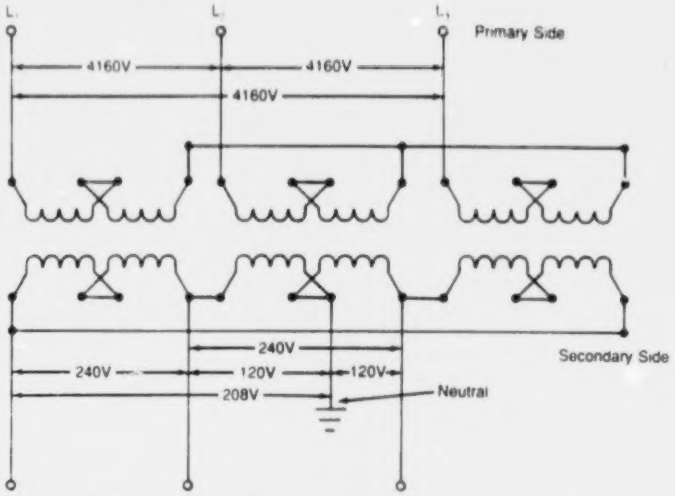
3. Most commonly used voltage systems

a. Single phase transformers


Primary Side
2400V
Neutral Wire Grounded
120V
120V
240V

Information Sheet

b. Three phase transformers



4. ***NEC* requirements for dry type transformers**

Note: Refer to *NEC* Article 450-21.

a. Dry type transformers installed indoors rated at 11.25 KVA or less must have a fire resistant, heat-insulating barrier between transformer and combustible materials. If a barrier is not used and voltage is over 600V, a 12″ minimum from combustible material is used.

b. Dry type transformers do not require a 12″ separation of barrier if they are enclosed and are rated less than 112.5 KVA and will operate at 600V or less.

c. Dry type transformers rated over 35,000 volts must be installed in a vault.

5. ***NEC* requirements for oil-filled transformers**

a. Oil-filled transformers can be installed indoors and outdoors. When mounted indoors, oil-filled transformers must be mounted in a vault.

b. *NEC* Article 450-26 pertains to oil-insulated transformers which are installed indoors.

Note: Read complete article and exceptions.

c. *NEC* Article 450-27 pertains to oil-insulated transformers which are installed outdoors.

Note: Read complete article and exceptions.

Information Sheet

6. ***NEC* requirements for askarel-filled transformers**

Note: Askarel-filled transformers release PCBs and should not be used on new installations.

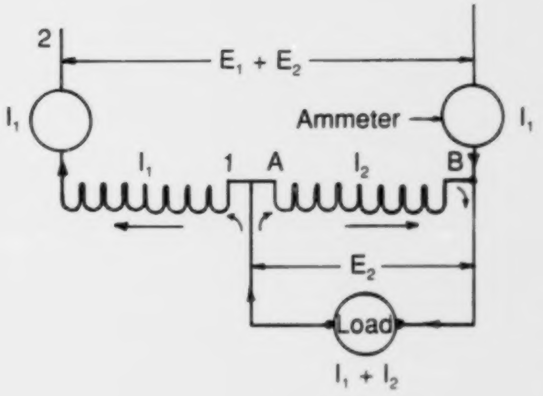
a. Askarel-filled transformers are filled with a liquid called askarel which will not burn and is nonexplosive. Gases are produced as a result of arcing. A vent is required if the transformer is over 25 KVA.

b. *NEC* Article 450-25 pertains to askarel-insulated transformers installed indoors.

Note: Read complete article on askarel transformers.

7. **Function of a buck and boost transformer** — It is used to increase or decrease voltage.

Note: The values used will depend on the line voltage and the amount of boost required. A buck and boost transformer is wired like an autotransformer.



8. ***NEC* articles concerning transformer locations**

Note: Some dry, oil-filled and askarel-filled transformers require vaults for their insulation. Read the following articles and exceptions.

a. *NEC* Article 450-41 pertains to the location of transformer vaults.

b. *NEC* Article 450-42 pertains to walls, roofs, and floors.

c. *NEC* Article 450-43 pertains to doorways.

d. *NEC* Article 450-45 pertains to ventilation openings.

e. *NEC* Article 450-47 pertains to water pipes and accessories.

f. *NEC* Article 450-48 pertains to storage in vaults.

Information Sheet

9. Installation and termination of transformers

a. Mounting of transformers must comply with the *NEC* on location, storage, and uses. Refer to *NEC* Article 450-2.

b. Grounding of transformers will comply with *NEC* Article 450-10.

c. Overcurrent protection may be installed on primary and secondary windings of transformers. Refer to:

- *NEC* Article 240-3, Exception No. 2
- *NEC* Article 240-21, Exceptions No. 2, No. 8, and No. 11
- *NEC* Article 384-16(d)

Transformers
Unit 4

Assignment Sheet 1—Locate and List Two Exceptions on Transformer Room Construction for Dry Type Transformers

Name ______________________________ Overall Rating __________

Evaluation Criteria	**Rating**
Proper use of *NEC* demonstrated	______
Correct exceptions listed	______

Directions: Using the *NEC*, locate and list two exceptions on transformer room construction for dry type transformers over 112.5 KVA. The above criteria will be used to evaluate your performance.

A. Exception No.______

B. Exception No.______

Transformers
Unit 4

Assignment Sheet 2—Locate and List Two Exceptions Concerning Oil-Insulated Transformers

Name ______________________________ Overall Rating __________

Evaluation Criteria	**Rating**
Proper use of *NEC* demonstrated	_____
Correct exceptions listed	_____

Directions: Using the *NEC*, locate and list two exceptions to the requirement that oil-insulated transformers installed indoors required vaults. The above criteria will be used to evaluate your performance.

A. Article ___________ Exception No. _____

B. Article ___________ Exception No. _____

Transformers
Unit 4

Assignment Sheet 3—Draw a Three-Phase Wye-Delta Transformer

Name ______________________________ Overall Rating __________

Evaluation Criteria	**Rating**
Correct transformer drawn	_____
Proper symbols used	_____
Neat, legible drawing	_____

Directions: In the space provided below, draw a three-phase wye-delta transformer. The above criteria will be used to evaluate your performance.

Transformers
Unit 4

Assignment Sheet 4—Convert Amperes to KVA on a Three-Phase System

Name ______________________ Overall Rating __________

Evaluation Criteria	**Rating**
Correct conversions obtained	______
Legible answers given	______

Directions: Convert the following amperes to KVA on a 480V three-phase system. The above criteria will be used to evaluate your performance.

A. 60.2 amps: ________________ KVA

B. 120 amps: ________________ KVA

C. 241 amps: ________________ KVA

D. 602 amps: ________________ KVA

Transformers
Unit 4

Job Sheet 1—Test Transformer Turn Ratios

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
Safety rules practiced throughout procedure	______
Voltmeters and transformers connected correctly	______
Voltmeter readings accurately recorded	______
Transformer turn ratios calculated correctly	______
Good workmanship	______
Compliance to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Transformer, rated 480 to 120/240 volt
Transformer, rated 240 to 24 volts
Transformer, rated 120 to 24 volts
Two voltmeters (one with 600-volt scale)
Wire or test jumpers to connect transformers to power supply
Single-phase power supply, 120/240-volt or 120/208-volt

B. Procedure

☐ 1. Observe safety rules throughout this procedure.

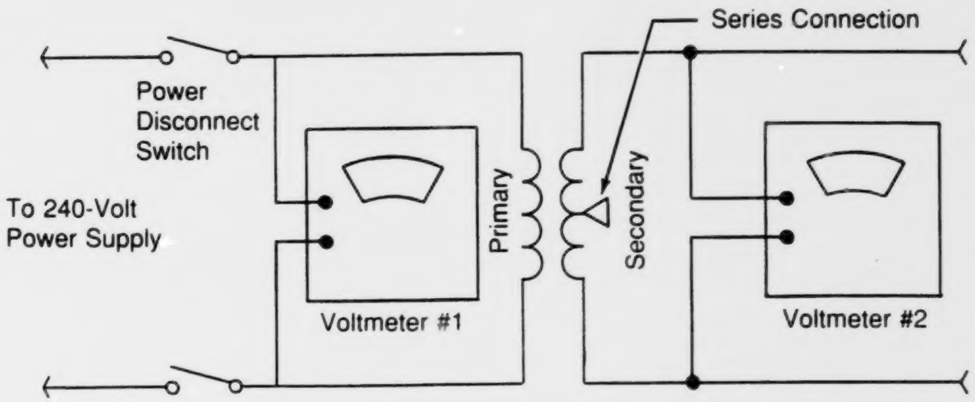
☐ 2. Check out proper tools and materials.

☐ 3. Connect both voltmeters to power supply, and adjust needles until both read the same at near midscale.

Job Sheet 1

☐ 4. Connect transformer as shown in Figure 1.

Figure 1


Series Connection
Power Disconnect Switch
To 240-Volt Power Supply
Primary
Secondary
Voltmeter #1
Voltmeter #2

☐ 5. Double-check connections for correctness.

☐ 6. Check to be sure that all leads are in the clear.

Note: Show work to instructor before proceeding.

☐ 7. Energize power supply.

☐ 8. Read both voltmeters.

☐ 9. Record voltmeter readings for Transformer #1.

VM #1 = ______________________________

VM #2 = ______________________________

☐ 10. Open power switch.

Job Sheet 1

☐ 11. Calculate actual transformer turn ration.

Note: Divide Voltmeter #2 reading by Voltmeter #1 reading to find the ratio. Show your work.

T#1 turn ration = ______________________________

☐ 12. Compare calculated ratio with nameplate voltage ratio.

Note: Calculated ratio should match nameplate within ± 1 percent.

☐ 13. Test Transformer #2, using the same procedure as that used to test Transformer #1.

☐ 14. Record voltmeter readings for Transformer #2 and calculate turn ratio.

Note: Show your work.

VM #1 = ______________________________

VM #2 = ______________________________

T#2 turn ratio = ______________________________

☐ 15. Test Transformer #3, using the same procedure as that used to test Transformer #1.

Job Sheet 1

☐ 16. Record voltmeter readings for Transformer #3 and calculate turn ratio.

Note: Show your work.

VM #1 = ______________________________

VM #2 = ______________________________

T#3 turn ratio = ______________________________

☐ 17. Return tools and materials to proper storage.

☐ 18. Clean the work area.

Evaluator's comments: ______________________________

____

____

Transformers
Unit 4

Job Sheet 2—Test Transformer Insulation Resistance

Name ____________________ Attempt Number ________

Date ____________________ Overall Rating ________

Evaluation Criteria	**Rating**
Safety rules practiced throughout procedure	______
Read instruments accurately	______
Properly recorded instrument readings	______
Good workmanship	______
Compliance to *NEC*	______

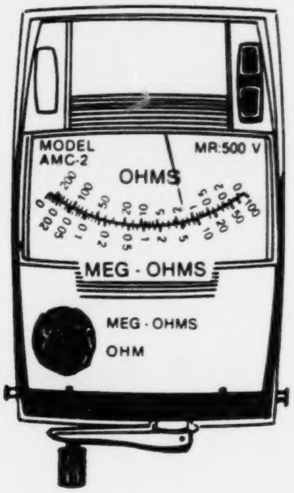
Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Three transformers (voltage not important; larger sizes if available)
Test jumpers or wires to short windings
Centigrade-scale thermometer
Megger tester with leads (Figure 1)

Job Sheet 2

Figure 1


MODEL
AMC-2
MR:500 V
OHMS
MEG - OHMS
MEG - OHMS
OHM

B. Procedure

☐ 1. Observe safety rules throughout this procedure.

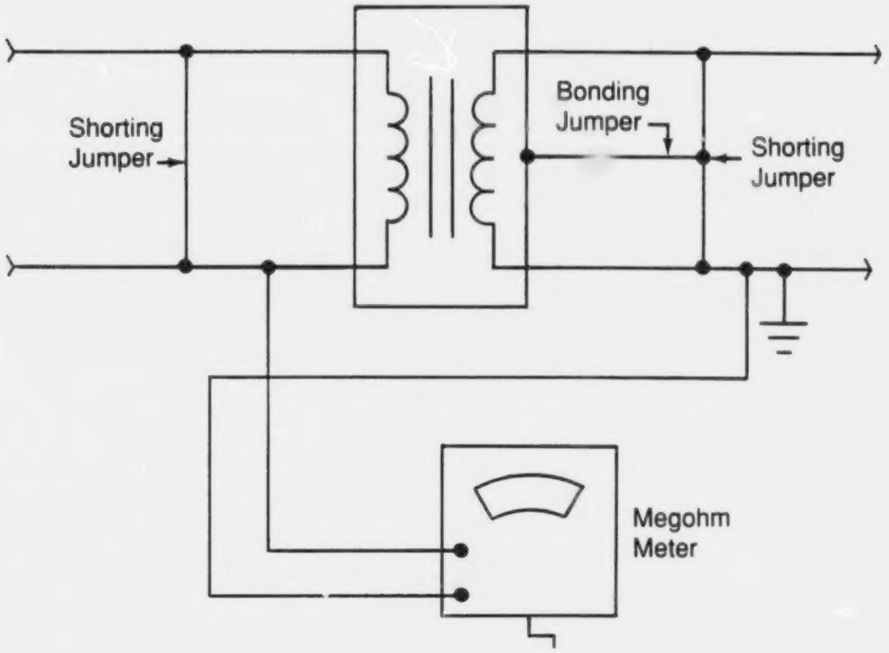
☐ 2. Check out proper tools and materials.

☐ 3. Test primary winding to secondary and ground.

Job Sheet 2

a. Construct circuit as shown in Figure 2.

Figure 2


Shorting Jumper
Bonding Jumper
Shorting Jumper
Megohm Meter

b. Short both windings.

c. Ground the secondary winding to transformer case.

d. As near as practicable, place thermometer to get the temperature of the interior of the windings.

e. Crank megger tester at about 120 rpm for sixty seconds or until needle settles down.

f. Read instrument while still cranking.

g. Stop cranking.

h. Record reading.

Megger reading = ________________________ Megohms

Job Sheet 2

i. Check thermometer.

Note: Insulation resistance will decrease by 50 percent for every 10-degree centigrade rise in temperature, or double for every 10-degree centigrade drop in temperature.

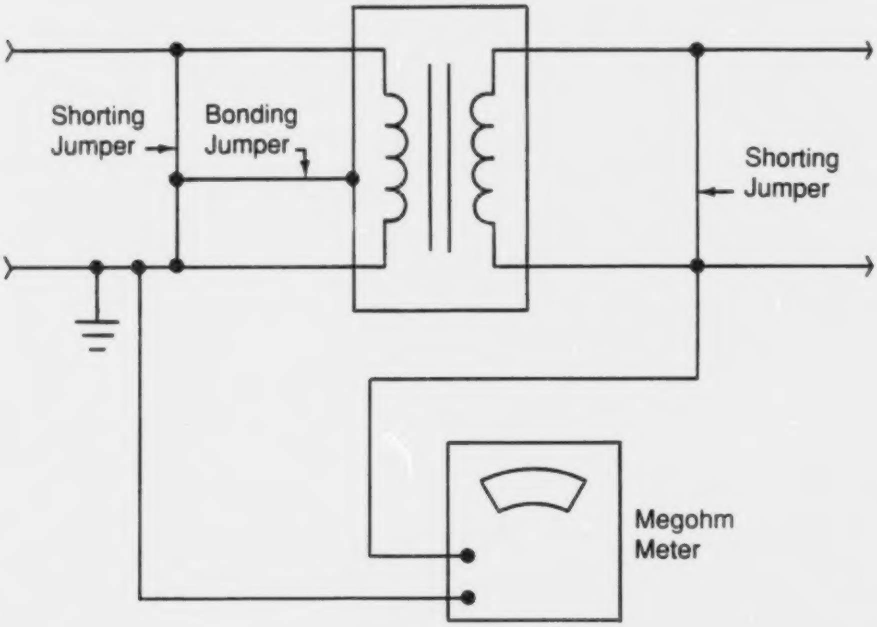
j. Record temperature.

Temperature = ________________________°C

Note:Megohm readings become more meaningful when periodic tests are made on a piece of equipment, and then plotted on graph paper to make a curve.

☐ 4. Test secondary to primary and ground.

Figure 3


Shorting Jumper
Bonding Jumper
Shorting Jumper
Megohm Meter

a. Short both windings.

b. Ground the primary winding to transformer case.

Job Sheet 2

c. Make tests as before on primary insulation.

Note: Follow Steps 3d through 3j.

Megger reading = ________________________ Megohms

Temperature = ________________________ °C

☐ 5. Repeat procedure on each remaining transformer.

a. Transformer #2

T2 megger reading = ________________________ Megohms

T2 temperature = ________________________ °C

b. Transformer #3

T3 megger reading = ________________________ Megohms

T3 temperature = ________________________ °C

☐ 6. Return tools and materials to proper storage.

☐ 7. Clean the work area.

Evaluator's comments: ____

____

____

Transformers
Unit 4

Job Sheet 3—Connect Transformer Primary and Secondary Windings in a Delta-Wye Configuration

Name ______________________________ Attempt Number __________

Date ______________________________ Overall Rating __________

Evaluation Criteria	Rating
Safety rules practiced throughout procedure	______
Transformers properly connected in delta-wye	______
Secured tight connections	______
Obtained correct readings	______
Good workmanship	______
Compliance to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Three-phase power supply, 240-volt

Note: A three-phase 208-volt power supply will also serve satisfactorily.

Three 5-ampere fuses in 240-volt circuit
#14 wire, approximately 20 feet
Wire nuts or bolts for connections
Three transformers rated 240 to 120/240 (200 volt-amperes to 1 kilovolt-ampere capacity)
Voltmeter with 600-volt scale
One lamp and socket, 100 watt, 120 volt

B. Procedure

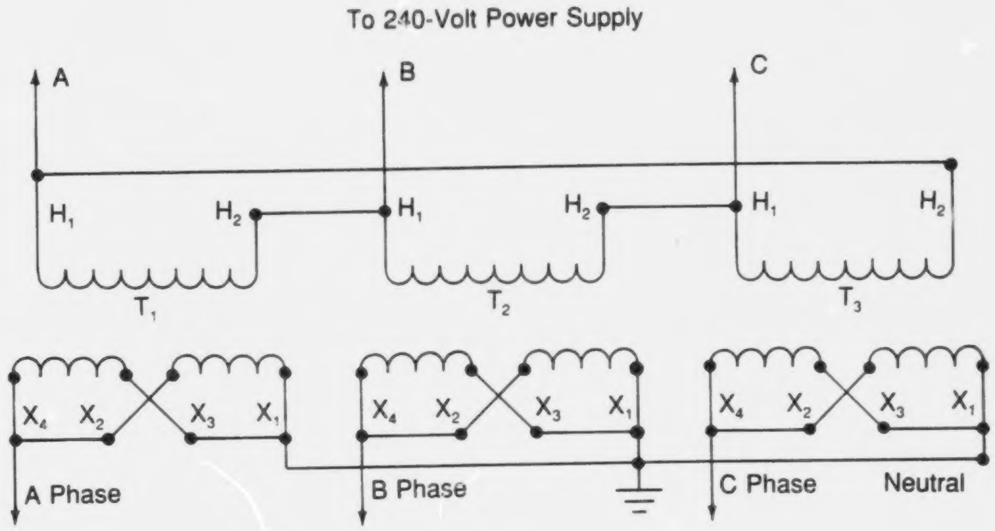
☐ 1. Observe safety rules throughout this procedure.

☐ 2. Check out proper tools and materials.

Job Sheet 3

☐ 3. Connect transformers in a delta primary to wye secondary configuration as shown in Figure 1.

Figure 1


To 240-Volt Power Supply
A
B
C
H_1
H_2
H_1
H_2
H_1
H_2
T_1
T_2
T_3
X_4
X_2
X_3
X_1
X_4
X_2
X_3
X_1
X_4
X_2
X_3
X_1
A Phase
B Phase
C Phase
Neutral

☐ 4. Double-check all connections for correctness.

Note: Show connections to instructor before proceeding.

☐ 5. Energize 240-volt circuit.

☐ 6. Read and record low-side voltages.

Phase A to B ______________________

Phase A to C ______________________

Phase B to C ______________________

Phase A to neutral ______________________

Phase B to neutral ______________________

Phase C to neutral ______________________

☐ 7. Deenergize 240-volt circuit.

Job Sheet 3

☐ 8. Connect 100-watt lamp to Phase A and neutral.

☐ 9. Reenergize 240-volt circuit.

☐ 10. Read and record voltages.

Phase A to neutral ________________________

Phase B to neutral ________________________

Phase C to neutral ________________________

☐ 11. Deenergize 240-volt circuit.

☐ 12. Connect the neutral to ground.

Note: An ungrounded neutral can shift when the load is unbalanced, causing low voltage at one point and high voltage at other points.

☐ 13. Read and record low-side voltages again.

Phase A to neutral ________________________

Phase B to neutral ________________________

Phase C to neutral ________________________

Phase A to B ________________________

Phase A to C ________________________

Phase B to C ________________________

☐ 14. Deenergize 240-volt circuit.

☐ 15. Disconnect T1 secondary leads from T2 and T3.

☐ 16. Connect terminal X4 of T1 to the neutral point.

☐ 17. Reenergize the circuit

Job Sheet 3

☐ 18. Read and record secondary voltages.

Phase A to B ______________________

Phase A to C ______________________

Phase B to C ______________________

Phase A to neutral ______________________

Phase B to neutral ______________________

Phase C to neutral ______________________

☐ 19. Return tools and materials to proper storage.

☐ 20. Clean the work area.

Evaluator's comments: ____

____

____

Rough-In
Unit 5

Objective Sheet

Unit Objective

After completing this unit, the student should be able to rough in a commercial or industrial job. The student should demonstrate these competencies by completing the assignment sheet and job sheets, and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to rough-in with their correct definitions.
2. Select true statements concerning branch circuit and feeder installation.
3. Identify devices used in special circuit installations.
4. Arrange in order the steps for determining the number of conductors allowed in a conduit, based on cross-sectional area.
5. List exceptions to the *NEC* requirements for support of flexible metal conduit.
6. Complete statements concerning optional calculations for additional loads to existing installations.
7. Determine the number of conductors allowed to be added to an existing conduit. (Assignment Sheet 1)
8. Rough in a wood framed wall. (Job Sheet 1)
9. Install outlet boxes on steel rods. (Job Sheet 2)
10. Install outlet boxes on steel studs using caddy metal stud clips for switch boxes. (Job Sheet 3)
11. Install masonry boxes in a block wall. (Job Sheet 4)

Rough-In
Unit 5

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.

2. Review Teaching Suggestions section that follows. Plan for classroom activities.

3. Plan for students with special needs.

4. Make transparencies from the transparency masters included with this unit. These appear in the teacher edition only and are designed to be used with the following objectives:

   TM 1 and 2—Bus Duct (Objective 4)
   TM 3—Cable Tray (Objective 4)
   TM 4—Cable Spacing in Cable Tray (Objective 4)

5. Make copies of the teacher supplement included with this unit.

6. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.

7. Develop teaching plan. Adjust for different learning styles.

8. Make copies of Unit Evaluation Form.

Delivery and Application

9. Provide students with unit of instruction.

10. Discuss unit and specific objectives.

11. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.

12. Discuss the assignment and job sheets. Review criteria for evaluation of these activities.

Suggested Activities

Evaluation

13. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

14. Make copies of the written test. Add or modify test items as needed.

15. Give written test.

16. Record assignment and job sheet ratings and written test scores on the Unit Evaluation Form. Add any additional assignments or supplemental activities that should be part of the unit evaluation.

17. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Take students on a field trip to a commercial job in the area. Discuss with students the different areas being roughed in. Skill areas: **listening** and **oral communication**.

2. Have a representative from a local supply house give a demonstration of trim out devices. Skill area: **listening**.

3. Invite a local electrical contractor to class to talk about commercial jobs. Have students prepare written questions prior to the talk and ask them after the presentation. Skill areas: **writing**, **listening**, and **oral communication**.

4. Set up several live troubleshooting projects in the lab, and demonstrate and discuss troubleshooting procedures. Distribute Teacher Supplement 1—Troubleshooting Procedures at this time. Skill area: **problem solving**.

   Note: The teaching of troubleshooting skills should be integrated throughout this publication.

Resources Used in Developing This Unit

1. Croft, Terrell and Wilford I. Summers. *American Electrician's Handbook*, 11th Ed. New York: McGraw-Hill Book Company, 1987.

Suggested Activities

2. Earley, Mark W., John M. Caloggero and Richard H. Murray. *NEC Handbook 1993.* Quincy, MA: National Fire Protection Association, 1992.

3. Kaltwasser, Stan and Gary Flowers. *Commercial and Industrial Wiring.* Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1988.

4. *National Electrical Code 1993.* Quincy, MA: National Fire Protection Association, 1992.

5. Teague, Cash and Garner Pewewardy. *Industrial Electricity: In-Plant Distribution.* Stillwater, OK: Oklahoma Curriculum and Instructional Materials Center, 1984.

Suggested Supplemental Resource

1. O'Riley, Ronald P. *Illustrated Changes in the 1993 National Electrical Code.* Albany, NY: Delmar Publishers, Inc. 1993.

Instructions for Evaluating Student Performance

Assignment Sheets—Be sure the student understands the criteria on which the evaluation is based. Assign a point value to each criterion and convert the total points to a percentage for grading.

Job Sheets—Be sure the student understands the criteria on which the evaluation is based. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher edition or student manual. Then observe the student performing the procedure. Rate both process and product.

> Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.
>
> Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. Complete the rating by assigning a point value to each criterion and by converting the point total to a percentage for grading. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Suggested Activities

Sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) which best fits your program needs.

Option A

4 - Skilled—Can perform job with no additional training.

3 - Moderately skilled—Has performed job during training program; limited additional training may be required.

2 - Limited skill—Has performed job during training program; additional training is required to develop skill.

1 - Unskilled—Is familiar with process, but is unable to perform job.

Option B

Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

Rough-In
Unit 5

Answers to Assignment Sheet 1

A. .21 sq. in. conduit area
.0311 sq. in. #10 THW

.0311
× 6
.1866 sq. in.

.1866 is less than .21; therefore, the additional conductors are allowed.

B. .12 sq. in. conduit area
.0117 sq. in. #12 THHN

.0117
× 7
.0819 sq. in.

.0819 is less than .12; therefore, the additional conductors are allowed.

C. .82 sq. in. conduit area
.2367 sq. in. for I/O THW
.0519 sq. in. for #6 THHN

.2367
× 3
.7101 sq. in.

.0519
× 3
.1557 sq. in.

.7101
+.1557
.8658 sq. in.

.8658 is greater than .82; therefore, a new conduit must be run.

Rough-In
Unit 5

Answers to Written Test

1.

a.	4	f.	17	k.	15	p.	7
b.	16	g.	19	l.	18	q.	9
c.	14	h.	8	m.	3	r.	10
d.	1	i.	2	n.	6	s.	20
e.	13	j.	5	o.	11	t.	12

2. a, c, d

3. a. Bus duct
   b. Cable tray

4. a. 4
   b. 1
   c. 5
   d. 3
   e. 2

5. Any two of the following:

   a. Where flexible metal conduit is fished
   b. Lengths not exceeding three feet
   c. Lengths not exceeding six feet from a fixture terminal connection to lighting fixtures

6. a. One year
   b. Rating
   c. Overcurrent protection

Rough-In
Unit 5

Written Test

Name ______________________________ Score ____________

1. Match the terms on the right with their correct definitions.

______a. Assigning colors to conductors based on their uses

______b. The systematic diagnosis of a malfunction

______c. An enclosed channel designed expressly for holding wires, cables, or busbars, with additional functions as permitted in the *National Electrical Code*

______d. The current in amperes that a conductor can carry continuously under the conditions of use without exceeding its temperature rating

______e. Strong rope of nylon or other substance used to pull heavy conductors into raceways

______f. Maximum and mininum voltage at which a device is designed to operate

______g. Compound of soap and other substances used to lubricate conductors being pulled or pushed into a raceway

______h. Establishing a connection between two points so a cable or length of flexible conduit can be installed

______i. Mechanical or hydraulic device used to bend heavy conductors in panels and junction boxes

1. Ampacity
2. Cable bender
3. Copper-clad aluminum
4. Color coding
5. Covered
6. Cross-sectional area
7. Drop chain
8. Fish
9. Fish tape
10. Insulated
11. Pipe chase
12. Power fish-tape system
13. Pull rope
14. Raceway
15. Trim out
16. Troubleshooting
17. Voltage rating
18. Wire dispenser

Written Test

______j. Conductor encased within material of composition and thickness not recognized by the *National Electrical Code* as electrical insulation

______k. Final stage in a wiring project: involves devices and plates, connecting and securing equipment, hanging fixtures, and testing the system

______l. Movable rack used to hold one or more reels of wire so that wire can be easily pulled off reel and fed into raceway

______m. Aluminum conductor with an outer coating of copper metallurgically bonded to the aluminum core

______n. Area in square inches allowed in a raceway

______o. Usually a vertical space between two floors, dedicated for the running of pipes and conduits between floors

______p. Short length of small chain used to pull conductors or flexible conduit through an enclosed space or wall cavity

______q. Long tape of steel, nylon, or other material used to push or pull conductors into a raceway

______r. Conductor encased within material of composition and thickness recognized by the *National Electrical Code* as electrical insulation

______s. Manual or motor-powered mechanical device used to pull conductors into a raceway

______t. Vacuum or air pressure system for installing a pull cord in a raceway in order to pull in the heavy pull rope for heavy and long pulls

19. Wire-pulling compound
20. Winch

Written Test

2. Select true statements concerning branch circuit and feeder installation by placing an "X" in the blank preceding each true statement.

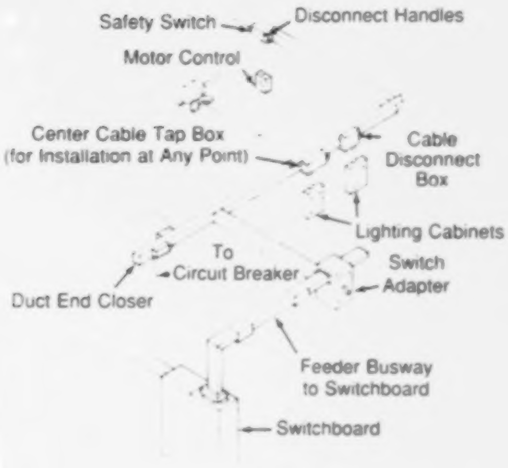
   ______a. When using multi-phase circuitry, balancing must take place to regulate the even flow of current on each of the phases.

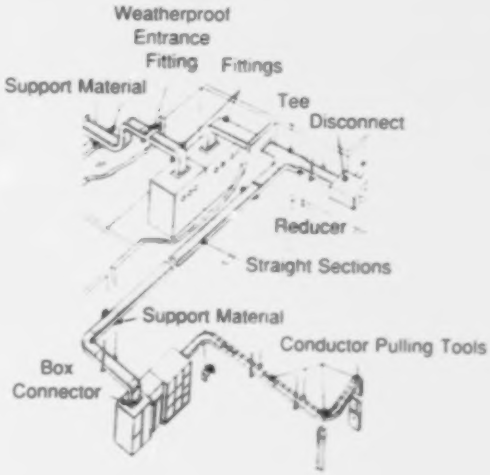
   ______b. Color coding for a high leg delta 4-wire system must be marked with yellow color and must be located on center lug.

   ______c. When identifying neutrals, the *NEC* states that conductors not white must be marked with continuous white or gray tape, or white paint.

   ______d. Temporary lighting shall be protected from accidental contact or breakage by a suitable fixture or lampholder with a guard.

3. Identify devices used in special circuit installations.


Safety Switch
Disconnect Handles
Motor Control
Center Cable Tap Box (for Installation at Any Point)
Cable Disconnect Box
Lighting Cabinets
To Circuit Breaker
Switch Adapter
Duct End Closer
Feeder Busway to Switchboard
Switchboard


Weatherproof Entrance Fitting
Fittings
Support Material
Tee
Disconnect
Reducer
Straight Sections
Support Material
Conductor Pulling Tools
Box Connector

a. ________________________

b. ________________________

Written Test

4. Arrange in order the steps for determining the number of conductors allowed in a conduit based on cross-sectional area by numbering from 1 to 5.

   ______a. Compute total area occupied by existing conductors based on Table 5, Chapter 9 of the *NEC*.

   ______b. Determine size of existing conduit.

   ______c. Determine number of conductors that may be added.

   ______d. Find area of conduit or tubing using Table 4, Chapter 9 of the *NEC*.

   ______e. Determine number and size of existing conductors.

5. List two exceptions to the *NEC* requirements for support of flexible metal conduit.

   a. ____

   ____

   ____

   b. ____

   ____

   ____

6. Complete the following statements concerning conditions for using the optional calculations for additional loads to existing installations.

   a. The maximum demand data is available in KVA for a minimum of a ____________________ period.

   b. The existing demand at 125 percent plus the new load does not exceed the ampacity of the feeders or ____________________ of the service.

   c. The feeder or service has ______________________________ in accordance with sections 230-90 and 240-3 of the *NEC*.

*Permission to duplicate this test is granted.

Rough-In
Unit 5

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Assignment Sheet 1—Determine the Number of Conductors Allowed to be Added to an Existing Conduit Rating ______

Comments: ____

____

Job Sheet 1—Rough In a Wood Framed Wall Rating ______

Comments: ____

____

Job Sheet 2—Install Outlet Boxes on Steel Rods Rating ______

Comments: ____

____

Job Sheet 3—Install Outlet Boxes on Steel Studs Using Caddy Metal Stud Clips for Switch Boxes Rating ______

Comments: ____

____

Job Sheet 4—Install Masonry Boxes in a Block Wall Rating ______

Comments: ____

____

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ____

____

Teacher Signature ______________________________ Date __________

Student Signature ______________________________ Date __________

***Permission to duplicate this form is granted.**

Rough-In
Unit 5

Teacher Supplement 1—Troubleshooting Procedures

1. Determine the symptoms of the system malfunction. Consult the owner about the operation of the system before, during, and after the problem occurred.

   Note: A great deal of information can be gained from this questioning—Did it flicker, hum, or explode? Was anything unusual going on at the time of the problem (lightning, unusual load, too many appliances plugged in)? Has it happened before?

2. Inspect the system.

   Note: The panel is the place to start, because the overcurrent protection device will identify the problem circuit. Most national, state, and local codes require that panels be identified.

   a. Trace the system from the panel by:

      - Color of conductor
      - Number of conductor
      - Using an ohmmeter

      > **Caution: Always disconnect the supply power from the circuit to be tested before using an ohmmeter. Line voltages will damage the meter.**

   b. Check the conductor's condition.

      - Is the conductor discolored from overheating?
      - Is the conductor insulation damaged or nicked?
      - Is there a loose conductor connection at devices or splice points?

   c. Check devices or fixtures

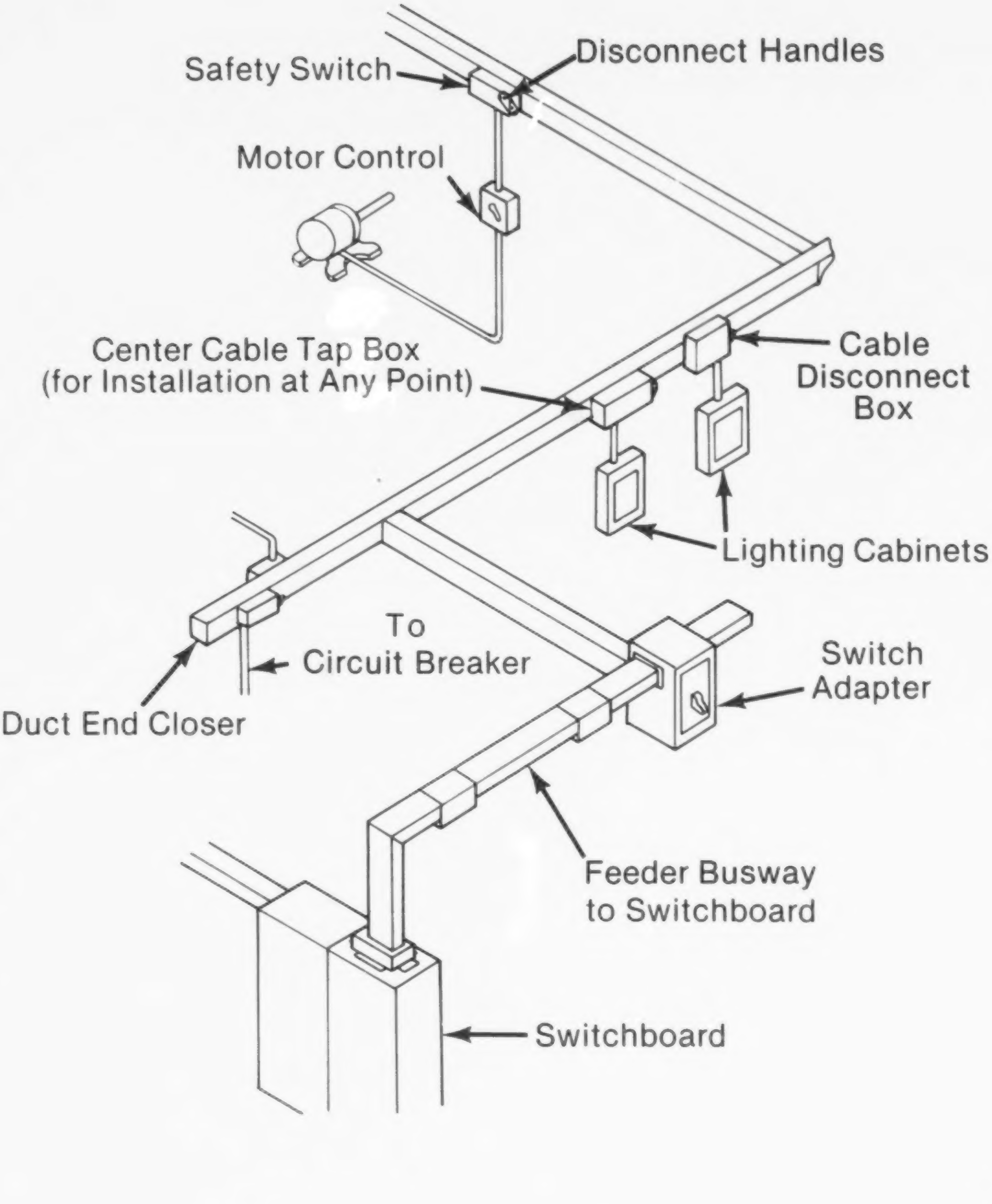
      - Is the device worn or overheated?
      - Is the fixture worn or overheated?
      - Is there reversed outlet polarity which may cause neutral overload?

        Note: Fixtures with bulbs larger than their rating may have internal damage.

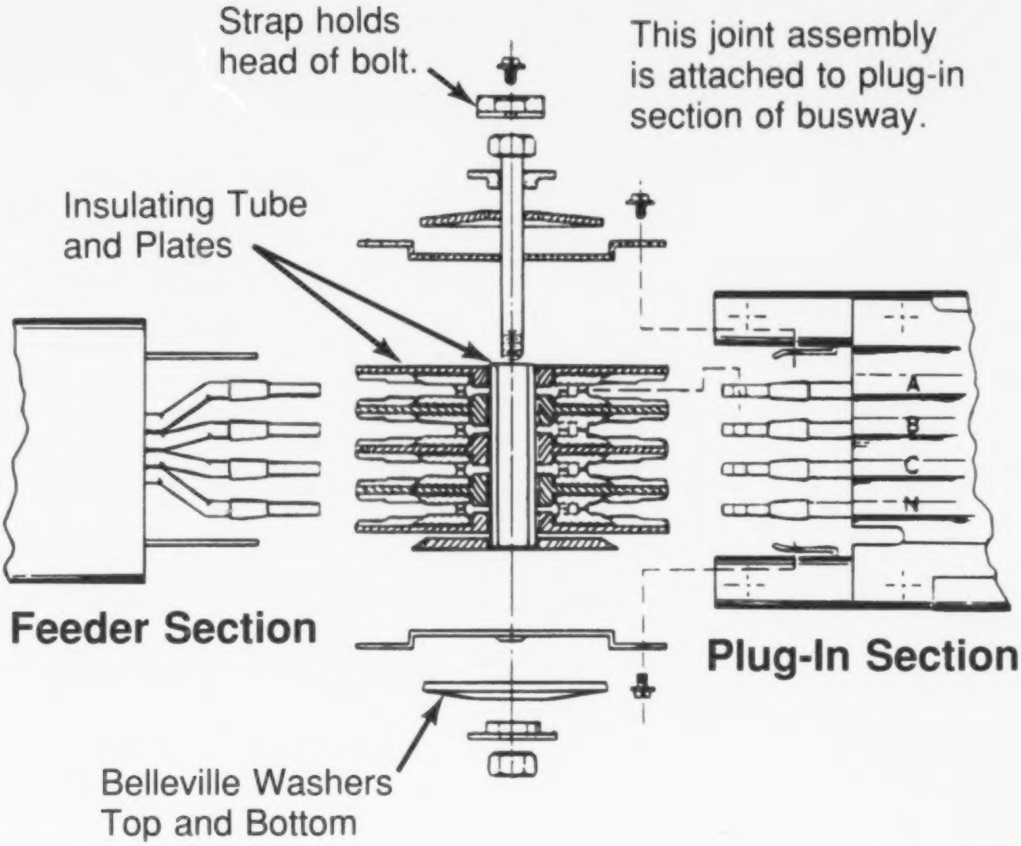
Teacher Supplement 1

3. Locate the problem causing area.
   - Is it a bad device or fixture?
   - Is it a broken conductor?
   - Is it a circuit overload?
4. Repair or replace the cause of the problem.
   - Install a new device or fixture.
   - Rewire the circuit.
   - Install an extra circuit to compensate for overload.

Bus Duct


Safety Switch
Disconnect Handles
Motor Control
Center Cable Tap Box
(for Installation at Any Point)
Cable
Disconnect
Box
Lighting Cabinets
To
Circuit Breaker
Duct End Closer
Switch
Adapter
Feeder Busway
to Switchboard
Switchboard

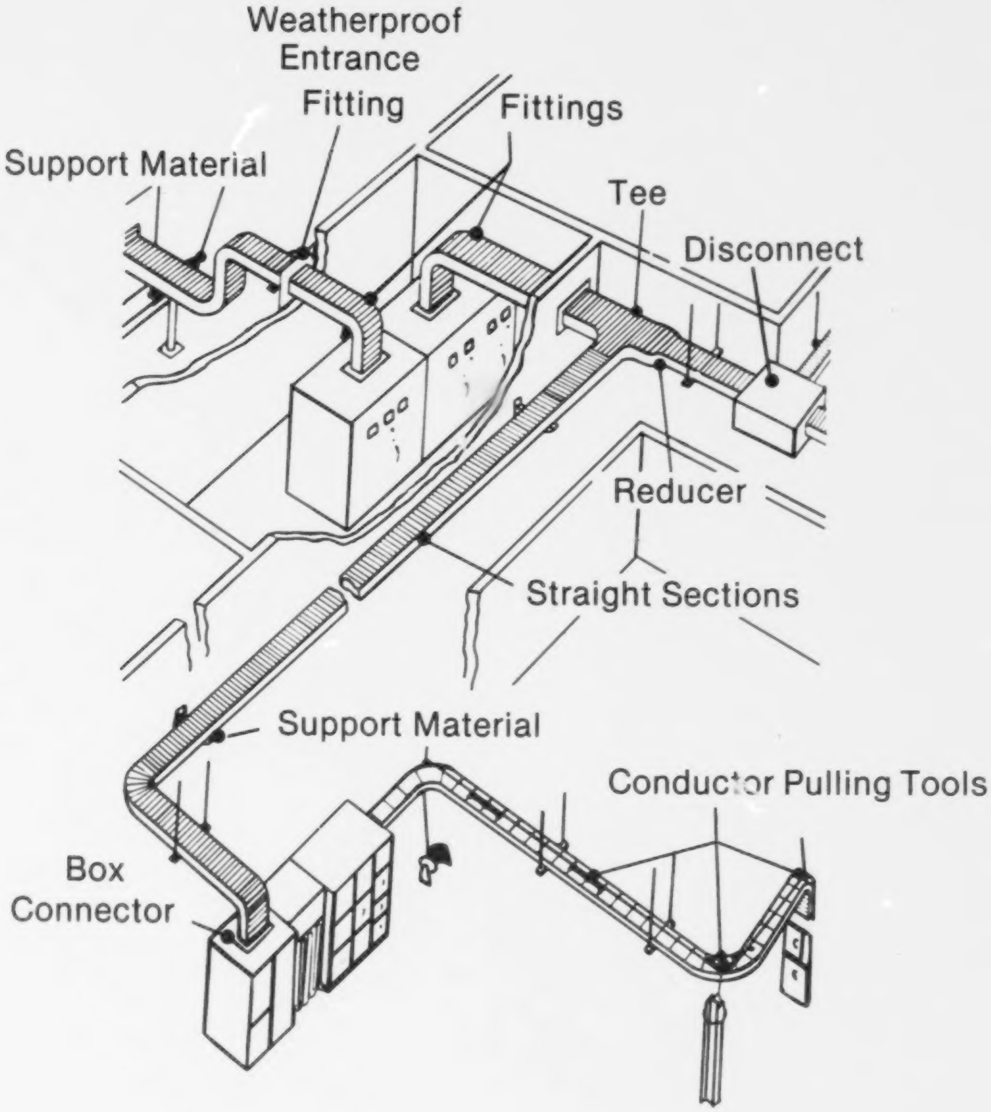
Bus Duct
(Continued)


Strap holds head of bolt.
This joint assembly is attached to plug-in section of busway.
Insulating Tube and Plates
Feeder Section
A
B
C
N
Plug-In Section
Belleville Washers Top and Bottom

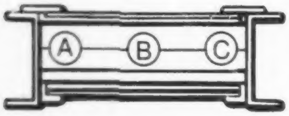
One Bolt Joint Assembly

*Used with permission of Cutler-Hammer Products/Eaton Corporation.

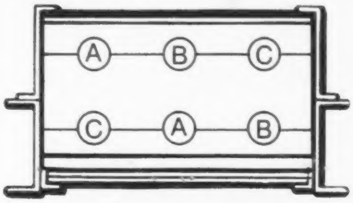
Cable Tray


Weatherproof Entrance Fitting
Fittings
Support Material
Tee
Disconnect
Reducer
Straight Sections
Support Material
Conductor Pulling Tools
Box Connector

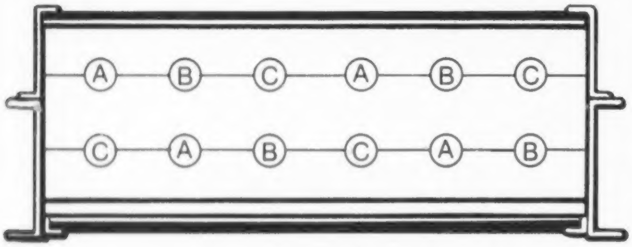
Cable Spacing in Cable Tray



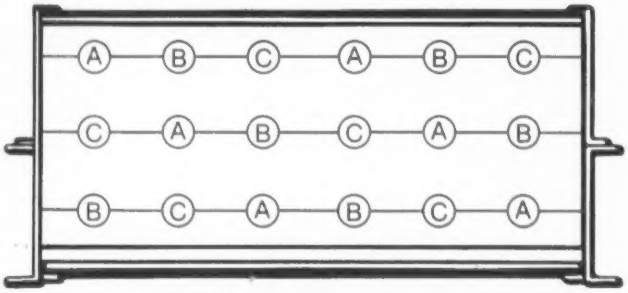
3 - Conductor



6 - Conductor


A
B
C
A
B
C
C
A
B
C
A
B

12 - Conductor


A
B
C
A
B
C
C
A
B
C
A
B
B
C
A
B
C
A

18 - Conductor

Rough-In
Unit 5

Information Sheet

1. **Terms and definitions**

   a. **Ampacity** — The current in amperes that a conductor can carry continuously under the conditions of use without exceeding its temperature rating

   b. **Cable bender** — Mechanical or hydraulic device used to bend heavy conductors in panels and junction boxes

   c. **Copper-clad aluminum** — Aluminum conductor with an outer coating of copper metallurgically bonded to the aluminum core

   d. **Color coding** — Assigning colors to conductors based on their uses

   e. **Covered** — Conductor encased within material of composition and thickness not recognized by the *National Electrical Code* as electrical insulation

   f. **Cross-sectional area** — Area in square inches allowed in a raceway

   g. **Drop chain** — Short length of small chain used to pull conductors or flexible conduit through an enclosed space or wall cavity

   h. **Fish** — Establishing a connection between two points so a cable or length of flexible conduit can be installed

   i. **Fish tape** — Long tape of steel, nylon, or other material used to push or pull conductors into a raceway

   j. **Insulated** — Conductor encased within material of composition and thickness recognized by the *National Electrical Code* as electrical insulation

   k. **Pipe chase** — Usually a vertical space between two floors, dedicated for the running of pipes and conduits between floors

   l. **Power fish-tape system** — Vacuum or air pressure system for installing a pull cord in a raceway in order to pull in the heavy pull rope for heavy and long pulls

   m. **Pull rope** — Strong rope of nylon or other substance used to pull heavy conductors into raceways

   n. **Raceway** — An enclosed channel designed expressly for holding wires, cables, or busbars, with additional functions as permitted in the *National Electrical Code*

Information Sheet

o. **Trim out** — Final stage in a wiring project; involves devices and plates, connecting and securing equipment, hanging fixtures, and testing the system

p. **Troubleshooting** — The systematic diagnosis of a malfunction

q. **Voltage rating** — Maximum and minimum voltage at which a device is designed to operate

r. **Winch** — Manual or motor-powered mechanical device used to pull conductors into a raceway

s. **Wire dispenser** — Movable rack used to hold one or more reels of wire so that wire can be easily pulled off reel and fed into raceway

t. **Wire-pulling compound** — Compound of soap and other substances used to lubricate conductors being pulled or pushed into a raceway

2. **Branch circuit and feeder installation**

a. When using multi-phase circuitry, balancing must take place to regulate the even flow of current on each of the phases. This is done by connecting an ammeter to the incoming conductor. By using the reading, circuits may be moved to balance the load by switching conductors with different phases.

b. Color coding for a high leg delta 4-wire system must be marked with orange color (refer to *NEC* Article 215-8) and must be located on center lug (refer to *NEC* Article 384-3F) when neutral is present.

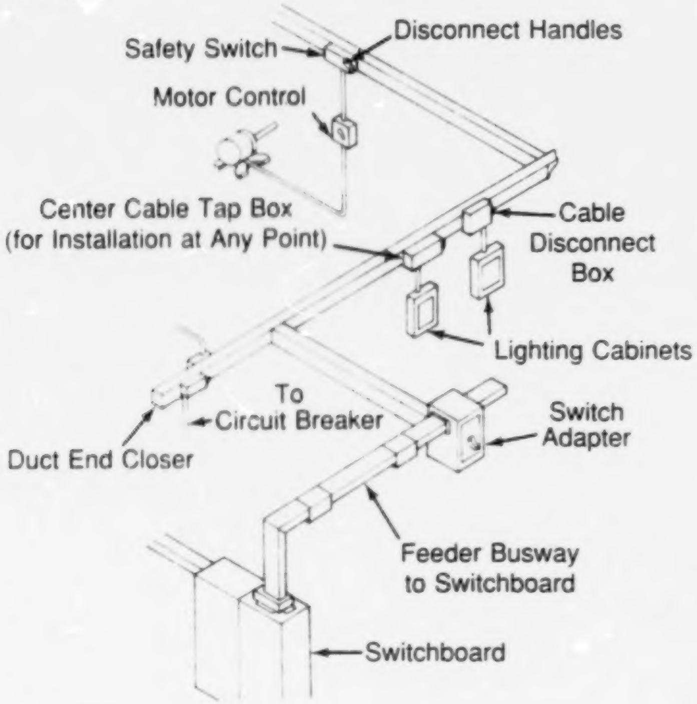
c. When identifying neutrals, *NEC* Section 200-6 states that conductors not white must be marked with continuous white or gray tape, or white paint.

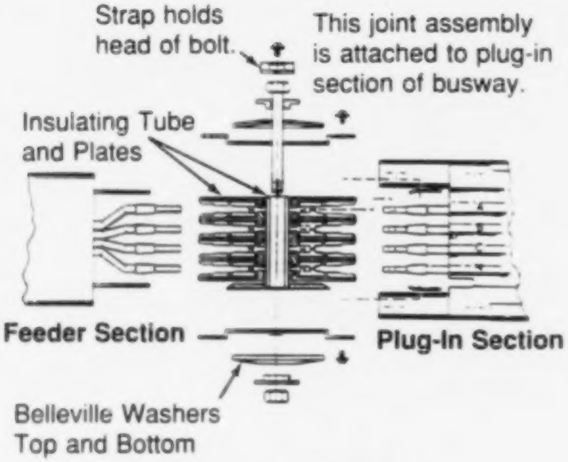
d. Temporary wiring and lighting must comply with *NEC* Article 305, which states that temporary power shall be equipped with GFI protection. Temporary lighting shall be protected from accidental contact or breakage by a suitable fixture or lampholder with a guard.

Information Sheet

3. Devices used in special circuit installations

a. Bus duct


Safety Switch
Disconnect Handles
Motor Control
Center Cable Tap Box
(for Installation at Any Point)
Cable
Disconnect
Box
Lighting Cabinets
To
Circuit Breaker
Duct End Closer
Switch
Adapter
Feeder Busway
to Switchboard
Switchboard


Strap holds
head of bolt.
This joint assembly
is attached to plug-in
section of busway.
Insulating Tube
and Plates
Feeder Section
Plug-In Section
Belleville Washers
Top and Bottom

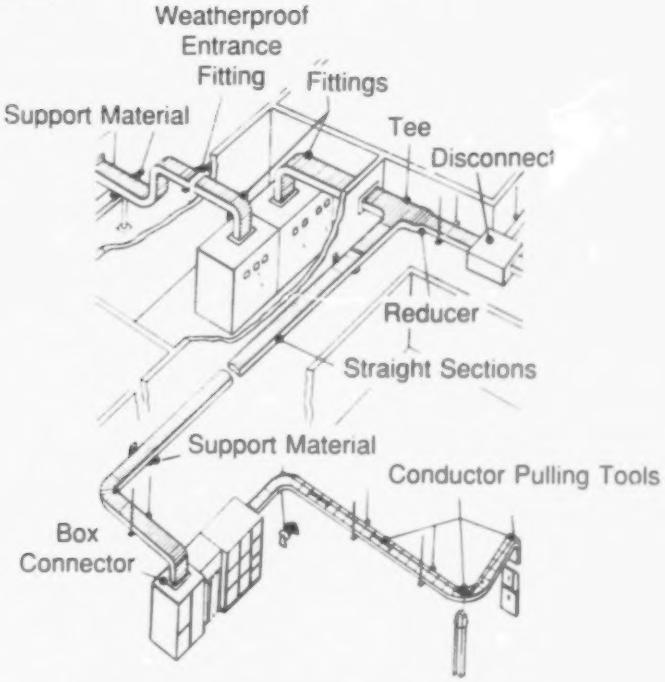
One Bolt Joint Assembly

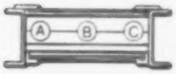
---

*Used with permission of Cutler-Hammer Products/Eaton Corporation.

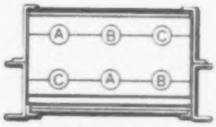
Information Sheet

b. Cable tray

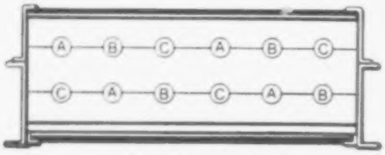

Weatherproof Entrance Fitting
Fittings
Support Material
Tee
Disconnect
Reducer
Straight Sections
Support Material
Conductor Pulling Tools
Box Connector



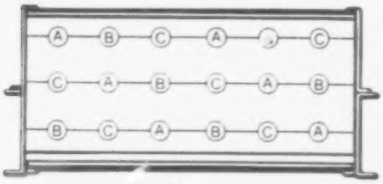
3 - Conductor



6 - Conductor


A B C A B C
C A B C A B

12 - Conductor


A B C A C
C A B C A B
B C A B C A

18 - Conductor

Information Sheet

4. **Steps for determining the number of conductors allowed in a conduit, based on cross-sectional area**

   a. Determine size of existing conduit.

   b. Determine number and size of existing conductors.

   c. Find area of conduit or tubing using Table 4, Chapter 9 of the *NEC*.

   d. Compute total area occupied by existing conductors based on Table 5, Chapter 9 of the *NEC*.

   e. Determine number of conductors that may be added.

Example: An existing 1-inch conduit contains three #8 THHN conductors. Four #12 THW conductors need to be added to feed a new circuit.

1-inch conduit with over two conductors not lead covered has an area of .34 square inches (Table 4, Chapter 9).

#8 THHN has an area of .0471 sq. in. (Table 5, Chapter 9).

.0471 sq. in.
× 3 conductors
.1413 sq. in.

#12 THW has an area of .0172 sq. in. (Table 5, Chapter 9).

.0172 sq. in.
× 4 conductors
.0688 sq. in.

Total area required for conductors is:

.1413
+.0688
.2101 sq. in.

.2101 is less than .34, therefore the four #12 THW conductors may be added.

Information Sheet

5. **Exceptions to the *NEC* requirements for support of flexible metal conduit**

   Note: Refer to *NEC* Article 350-4.

   a. Where flexible metal conduit is fished

   b. Lengths not exceeding three feet

   c. Lengths not exceeding six feet from a fixture terminal connection to lighting fixtures

6. **Optional calculations for additional loads to existing installations**

   Note: For the purpose of allowing additional loads to be connected to existing feeders and services, it shall be permitted to use the actual KVA demand figures to determine the existing load on a service or feeder when all the following conditions are met. Refer to *NEC* Articles 220-35(1) through (3).

   a. The maximum demand data is available in KVA for a minimum of a one year period.

   b. The existing demand at 125 percent plus the new load does not exceed the ampacity of the feeders or rating of the service.

   c. The feeder or service has overcurrent protection in accordance with sections 230-90 and 240-3 of the *NEC*.

      Note: *NEC* Article 230-90 requires overcurrent protection in each ungrounded conductor. Article 240-3 requires that conductors other than flexible cords and fixture wires be protected against overcurrent in accordance with their ampacities as specified in Tables 310-16 through 310-31 and all applicable notes to these tables.

Rough-In
Unit 5

Assignment Sheet 1—Determine the Number of Conductors Allowed to be Added to an Existing Conduit

Name ______________________ Overall Rating __________

Evaluation Criteria	**Rating**
Followed *NEC*	______
Obtained correct answers	______

Directions: Using the steps listed in Objective 4 of the Information Sheet and the *NEC*, determine if additional conductors may be added to a conduit or if a new conduit is necessary. Show your calculations. The above criteria will be used to evaluate your performance.

A. An existing ¾" conduit contains three #10 THW conductors; you need to add three more #10 THW conductors.

B. A ½" conduit contains three #12 THHN conductors. Will four more #12 THHN conductors be allowed?

C. A 1½" conduit contains three 1/O THW conductors. Will three #6 THHN conductors be allowed?

Rough-In
Unit 5

Job Sheet 1—Rough In a Wood Framed Wall

Name ________________________ Attempt Number ________

Date ________________________ Overall Rating ________

Evaluation Criteria	**Rating**
Safety rules practiced throughout procedure	______
Allowed for ⅝″ Sheetrock	______
Made accurate wall measurements	______
Correctly fastened bar hanger to studs	______
Demonstrated good workmanship	______
Complied to *NEC*	______

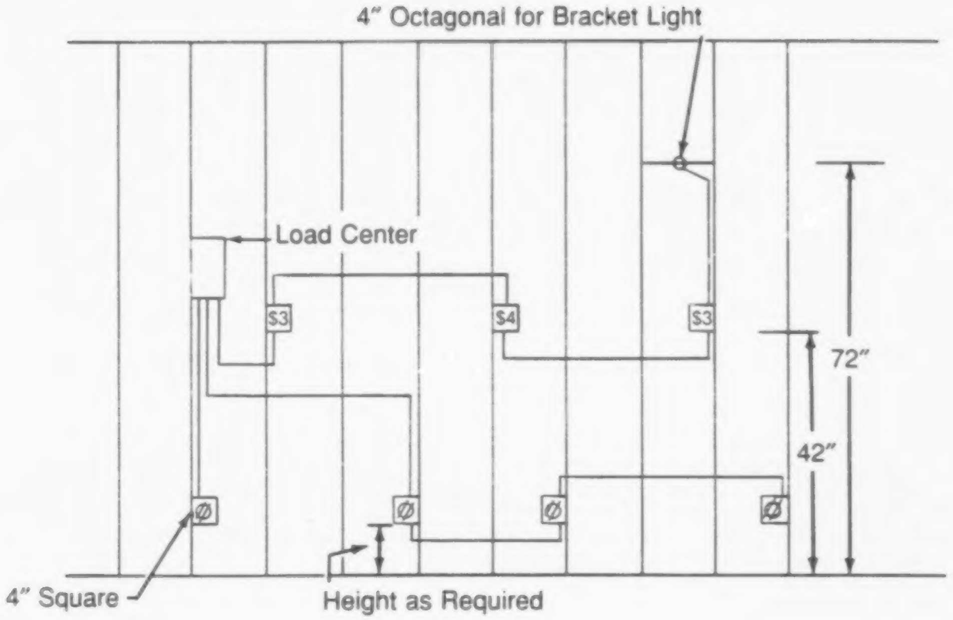
Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools, including hammer and tape
8-foot section of framed wall with 2″ × 4″ studs
Five outlet boxes, Raco #560 or equivalent
Two 4-inch square boxes, Raco #225 or equivalent
One plaster ring, Raco #772 or equivalent
One plaster ring, Raco #778 or equivalent
#8 mounting nails
4-inch octagonal box, Raco #125 or equivalent
One expandable hanger bar, Raco #924 or equivalent
One roll #12 THHN white
One roll #12 THHN black
One roll #12 THHN blue
One roll #12 THHN red
Forty feet of ½″ EMT
Construction blueprint showing locations and other necessary information for box installation as in Figure 1

Job Sheet 1

Figure 1



B. Procedure

☐ 1. Observe safety rules throughout this procedure.

☐ 2. Check out proper tools and materials.

☐ 3. View blueprint for installation information to determine location of boxes.

Note: Mount boxes to allow for ⅝-inch Sheetrock.

☐ 4. Lay out job by marking studs where boxes are to be installed.

☐ 5. Place boxes on floor along wall where each is to be installed.

☐ 6. Measure heights, and mark studs for mounting boxes.

Note: A quick accurate method for measuring for box installation is to cut a piece of conduit, lathe, or other similar material to proper length from floor or floor plate to bottom of box. Boxes can be held on top of the measuring device and fastened to the stud. This will prevent reading a rule for locating each box. A method often used in industry for height location of receptacle boxes is to set a hammer on the floor and position the box on top of the handle. The receptacle box can be fastened to the stud at that height.

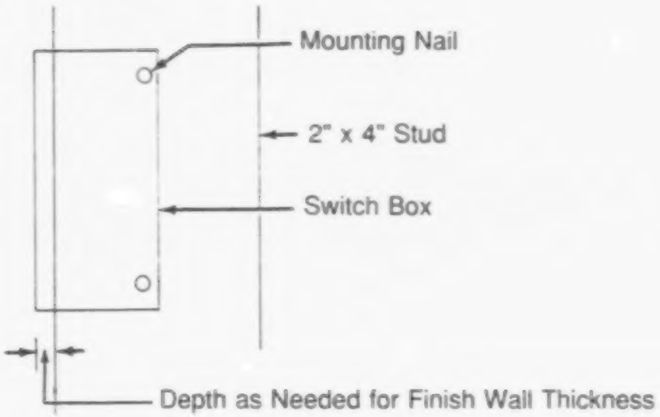
Job Sheet 1

☐ 7. Mount outlet boxes.

a. Mount electrical boxes to studs at the locations and heights marked, with front edge of boxes parallel to face of stud and extended ½ inch to allow for ⅝-inch Sheetrock.

Note: Four-inch square boxes are usually mounted with #8 or roofing nails, and switch boxes are usually mounted with #16 nails.

Figure 2

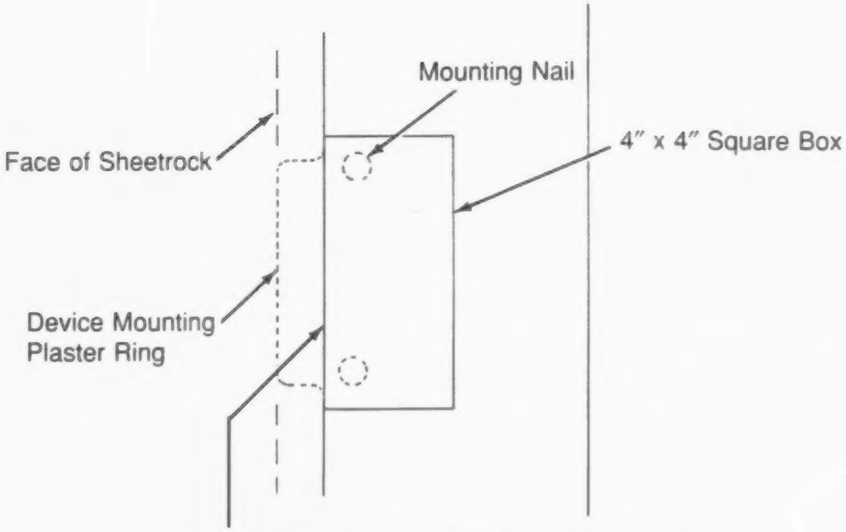

Mounting Nail
2" x 4" Stud
Switch Box
Depth as Needed for Finish Wall Thickness

Job Sheet 1

☐ 8. Mount 4-inch square boxes to studs at the height and location as marked with front edge of box flush with face of stud.

Note: Set four-inch square boxes ½ inch lower than switch boxes, with device screws inside.

Figure 3


Mounting Nail
Face of Sheetrock
4″ x 4″ Square Box
Device Mounting Plaster Ring

Front of box should be flush with 2″ x 4″ stud.

☐ 9. Install octagonal outlet box for wall bracket light between two studs at location and height marked.

a. Spread expandable hanger bar to proper length to fit between studs.

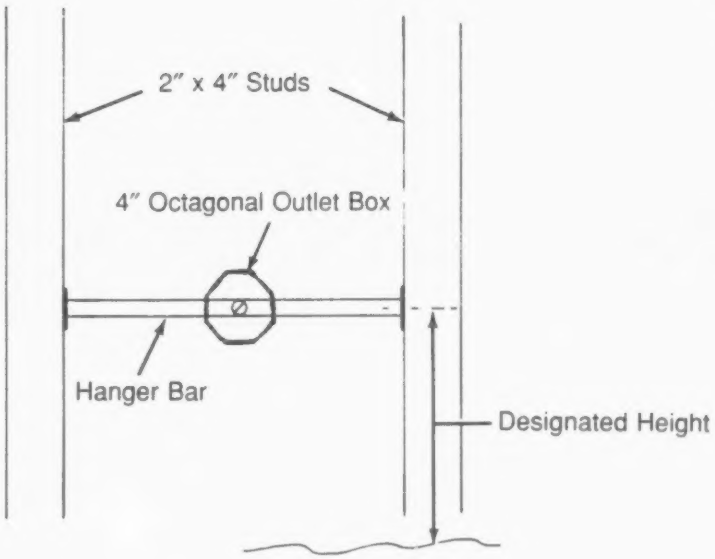
Job Sheet 1

b. Attach hanger bar to studs.

Note: Hanger bars are usually fastened to studs with #8 nails.

c. Attach octagonal outlet box to hanger bar.

Figure 4


2″ x 4″ Studs
4″ Octagonal Outlet Box
Hanger Bar
Designated Height

☐ 10. Rough in EMT runs.

☐ 11. Pull conductors and make up.

☐ 12. Return tools and materials to proper storage.

☐ 13. Clean the work area.

Evaluator's comments: ________________________________

____

____

Rough-In
Unit 5

Job Sheet 2—Install Outlet Boxes on Steel Rods

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
Safety rules practiced throughout procedure	______
Installed rods properly	______
Mounted hanger correctly	______
Fastened box properly	______
Leveled EMT	______
Connected box to EMT	______
Demonstrated good workmanship	______
Complied to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Stove bolt, ¼ inch by ½ inch
Three-foot piece of ½-inch EMT
Four-inch square outlet box, Raco #255 or equivalent
½-inch EMT connector
Two 3-foot pieces of ¼-inch rod
Two rod-hanger clamps, Caddy Catalog #708-2-4 or equivalent
Two conduit box clips, Caddy Catalog #4-1-2-4 or equivalent
Pouch tools

B. Procedure

☐ 1. Observe safety rules throughout this procedure.

☐ 2. Check out proper tools and materials.

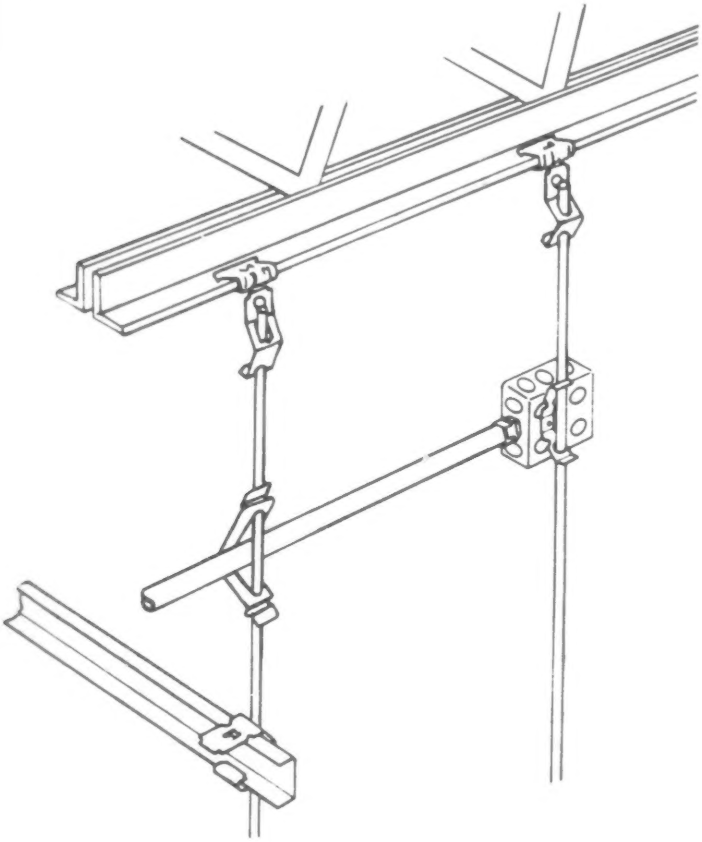
Job Sheet 2

☐ 3. Install two ¼-inch rods in rod-hanger clamps.

☐ 4. Mount two rod-hanger clamps on suspended angle iron approximately 24 inches apart.

☐ 5. Install ½-inch EMT in 4-inch square box.

Figure 1

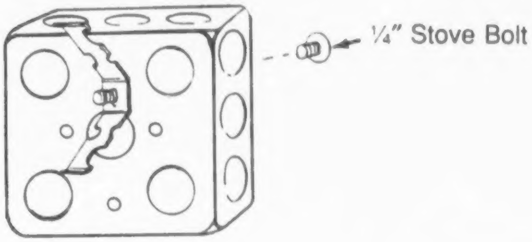


Used with permission of ERICO Products, Inc.

Job Sheet 2

☐ 6. Fasten rod-hanger clip to square box.

Figure 2

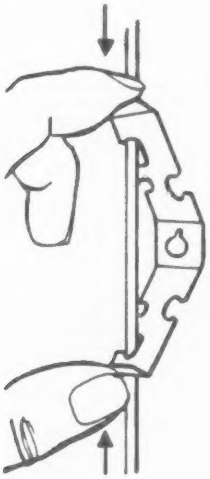


Used with permission of ERICO Products, Inc.

☐ 7. Mount box and EMT to the two ½-inch rods.

☐ 8. Adjust to proper height

Figure 3



Used with permission of ERICO Products, Inc.

Job Sheet 2

☐ 9. Return tools and materials to proper storage.

☐ 10. Clean the work area.

Evaluator's comments: ____

____

____

Rough-In
Unit 5

Job Sheet 3—Install Outlet Boxes on Steel Studs Using Caddy Metal Stud Clips for Switch Boxes

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
Safety rules practiced throughout procedure	______
Mounted clip to box	______
Mounted boxes to stud correctly	______
Mounted MF clip to box	______
Demonstrated good workmanship	______
Complied to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Hammer
Eight-foot section of steel stud wall
Three electrical boxes, Raco #560 or equivalent
Four-inch square electrical box, Raco #211 or equivalent
Handy box, Raco #660 or equivalent
Metal stud clip, Caddy #MSB-625 or equivalent
Four MF clips for switch boxes, Caddy #MF-625 or equivalent

B. Procedure

Note: Boxes may be mounted at nondesignated places because the intent of this job sheet is to acquaint students with box mounting methods when working with steel-stud walls.

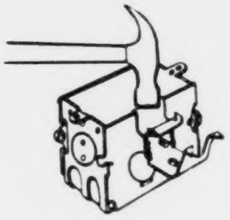
☐ 1. Observe safety rules throughout this procedure.

☐ 2. Check out proper tools and materials.

Job Sheet 3

☐ 3. Mount metal stud clip to switch box.

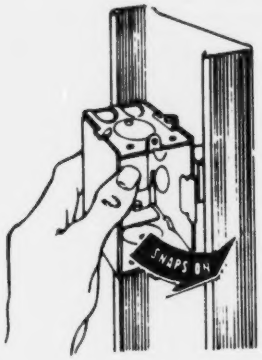
Figure 1



Used with permission of ERICO Products, Inc.

☐ 4. Mount box and clip to steel stud.

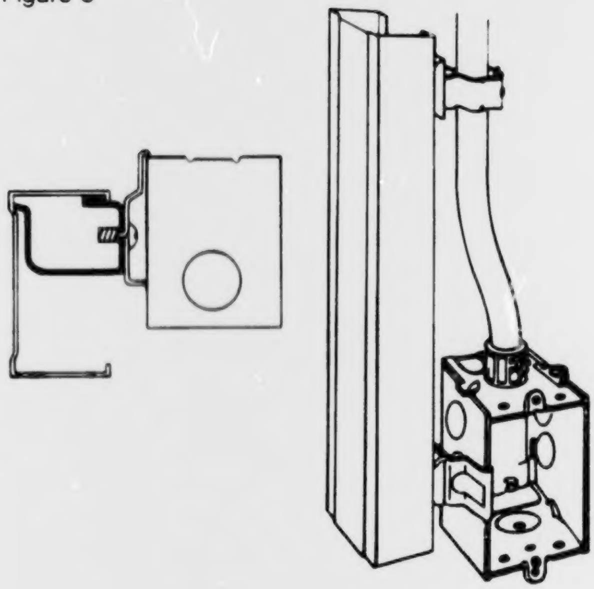
Figure 2



Used with permission of ERICO Products, Inc.

Job Sheet 3

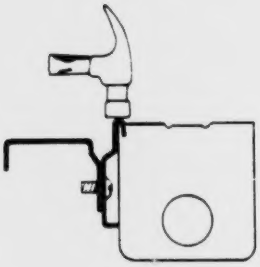
Figure 3



Used with permission of ERICO Products, Inc.

☐ 5. Mount one MF clip on each of the other boxes.

Figure 4

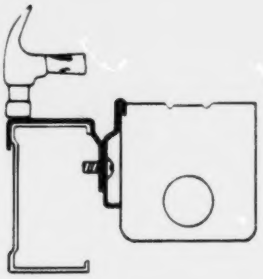


Used with permission of ERICO Products, Inc.

Job Sheet 3

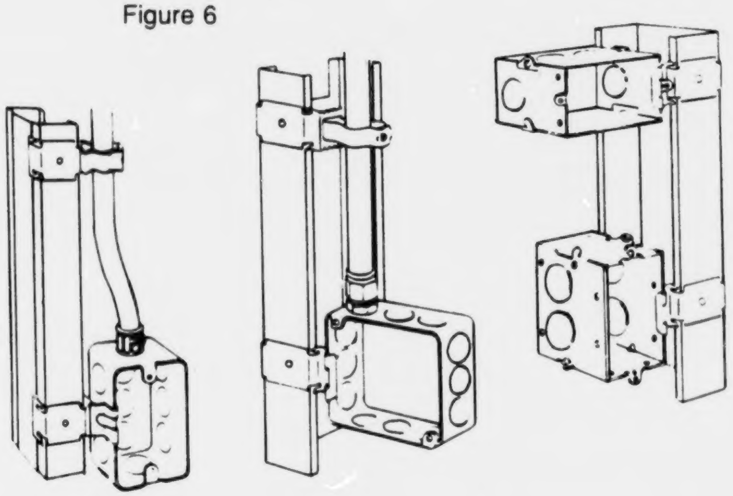
☐ 6. Mount clips and boxes to metal studs.

Figure 5



Used with permission of ERICO Products, Inc.

Figure 6



Used with permission of ERICO Products, Inc.

☐ 7. Return tools and equipment to proper storage.

☐ 8. Clean the work area.

Evaluator's comments: ____

____

____

Rough-In
Unit 5

Job Sheet 4—Install Masonry Boxes in a Block Wall

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating __________

Evaluation Criteria	**Rating**
Safety rules practiced throughout procedure	______
All pieces of EMT cut the same length (approx. 30″)	______
Installed connector in box properly	______
Connected coupling properly	______
Exact 90° bend made	______
Demonstrated good workmanship	______
Complied to *NEC*	______

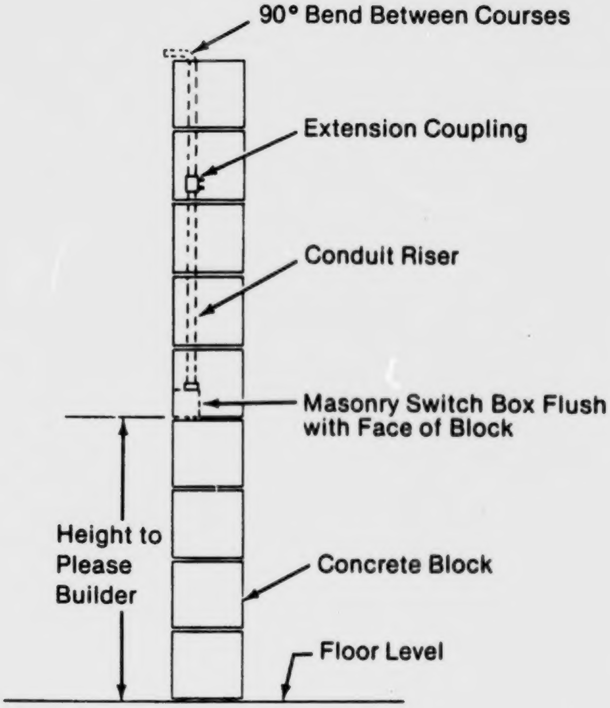
Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
Hacksaw
Two masonry switch boxes, Raco #695 or equivalent
Two masonry two-gang boxes, Raco #696 or equivalent
Twenty feet of ½-inch EMT
Four ½-inch EMT setscrew connectors
Four ½-inch EMT setscrew couplings
Conduit bender
Blueprint such as Figure 1

Job Sheet 4

Figure 1


90° Bend Between Courses
Extension Coupling
Conduit Riser
Masonry Switch Box Flush with Face of Block
Height to Please Builder
Concrete Block
Floor Level

B. Procedure

Note: This job must be done in cooperation with the masonry instructor because the electrical components are to be installed as the block wall is constructed.

☐ 1. Observe safety rules throughout this procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Open ½-inch knockout hole nearest to the back of box so that EMT will be in the hollow of the cement blocks.

Note: Masonry boxes generally have concentric ½-inch and ¾-inch knockout punchings; exercise care to break out only the ½-inch part.

☐ 4. Cut eight pieces of ½-inch EMT approximately 30 inches long.

Note: Cut all eight pieces exactly the same length.

Job Sheet 4

☐ 5. Install ½-inch EMT connectors in each of the four masonry box knockout holes.

Note: If during knockout removal, the ¾-inch punching breaks out instead of the ½-inch punching, see your instructor. You will need two ¾-inch by ½-inch reducing washers for each ¾-inch hole to properly install ½-inch EMT.

☐ 6. Install a 30-inch piece of EMT in each connector.

Note: The person laying the blocks must install each block down over the vertical conduit.

☐ 7. Deliver the made-up boxes to the block layer.

Note: The electrician and the block layer must work together to be sure that the boxes are installed in the proper locations, and correctly installed with the EMT extending upward in the wall. See Figure 1.

☐ 8. When the block wall reaches the desired height, install the masonry boxes with conduit extending upward.

☐ 9. Supervise the installation of the next layers of blocks until only a short portion of the conduit is visible above the wall.

Note: The block mason must raise the blocks above the height of the conduit, and then lower the next blocks over the conduit so that it extends upward through the hollow of the blocks.

☐ 10. Install 30-inch pieces of conduit equipped with couplings to increase the height for the next layers of blocks.

Note: The conduit is extended upward 2 or 3 feet at a time as the height of the wall increases.

☐ 11. Make a 90-degree bend in the conduit when the wall and conduit reach the required height.

Note: A 90-degree bend will allow the conduit to stick out of the wall between courses. This will prevent having to cut into the blocks.

☐ 12. Return tools and materials to proper storage.

☐ 13. Clean the work area.

Evaluator's comments: ______________________________

____

____

Lighting
Unit 6

Objective Sheet

Unit Objective

After completing this unit, the student should be able to troubleshoot and repair lighting fixtures. The student should demonstrate these competencies by completing the assignment sheet and job sheets, and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the students should be able to:

1. Match terms related to lighting with their correct definitions.
2. List basic types of lighting.
3. Select true statements concerning characteristics of incandescent lighting.
4. Complete statements concerning characteristics of fluorescent lighting.
5. Complete statements concerning characteristics of high intensity discharge lamps.
6. List methods of calculating light.
7. Complete statements concerning calculating branch circuits and voltage.
8. Select true statements concerning switching systems.
9. Locate articles in the *NEC* concerning lighting requirements. (Assignment Sheet 1)
10. Change a two-lamp ballast in a fluorescent fixture. (Job Sheet 1)
11. Change sockets in a fluorescent fixture. (Job Sheet 2)
12. Change an HID ballast. (Job Sheet 3)
13. Change a quartz lamp. (Job Sheet 4)

Lighting
Unit 6

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan for students with special needs.
4. Make copies of the teacher supplement included with this unit. This appears in the teacher edition only and is designed to be used throughout the unit.
5. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.
6. Develop teaching plan. Adjust for different learning styles.
7. Make copies of Unit Evaluation Form.

Delivery and Application

8. Provide students with unit of instruction.
9. Discuss unit and specific objectives.
10. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
11. Discuss the assignment and job sheets. Review criteria for evaluation of these activities.

Evaluation

12. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.
13. Make copies of the written test. Add or modify test items as needed.
14. Give written test.
15. Record assignment sheet and job sheet ratings and written test scores on the Unit Evaluation Form. Add any additional assignments or supplemental activities that should be part of the unit evaluation.
16. Reteach and retest as required.

Suggested Activities

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Invite a representative from a ballast company to show and discuss the various types of ballasts and their functions. Skill area: **listening**.
2. Show a film on advance ballast lighting. Skill area: **listening**.
3. Set up a display of the various types of lighting and point out special features.
4. Take students on a field trip to view different types of lighting used in commercial and industrial buildings. Have students take notes and discuss their observations in class. Skill areas: **writing** and **oral communication**.
5. Provide students with a copy of Teacher Supplement 1 — Troubleshooting Procedures. Discuss and demonstrate procedures. Skill areas: **reading** and **listening**.
6. Provide students with troubleshooting problems to practice the procedures listed in Teacher Supplement 1. Skill area: **problem solving**.

Resources Used in Developing This Unit

1. Kaltwasser, Stan and Gary Flowers. *Commercial and Industrial Wiring*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1988.
2. Mullin, Ray C. and Robert L. Smith. *Electrical Wiring: Commercial*, 8th Ed. Albany, NY: Delmar Publishers, Inc., 1993.
3. *National Electrical Code 1993*. Quincy, MA: National Fire Protection Association, 1992.
4. *Pocket Guide to Fluorescent Lamp Ballasts*. Carrolton, TX: Advance Transformer Company, 1986.
5. *Pocket Guide to HID Lamp Ballasts*. Carrolton, TX: Advance Transformer Company, 1986.

Note: Copies of the pocket guides listed in 4 and 5 may be obtained by writing to Advance Transformer Company, 10275 W. Higgins Rd., Rosemont, IL 60018. Telephone: 708/390-5000.

Suggested Activities

Suggested Supplemental Resources

1. Croft, Terrell and Wilford I. Summers. *American Electrician's Handbook*, 11th Ed. New York: McGraw-Hill Book Company, 1987.

2. Earley, Mark W., John Caloggero and Richard H. Murray. *NEC Handbook 1993*. Quincy, MA: National Fire Protection Association, 1992.

3. O'Riley, Ronald P. *Illustrated Changes in the 1993 National Electrical Code*. Albany, NY: Delmar Publishers, Inc., 1993.

Instructions for Evaluating Student Performance

Assignment Sheets—Be sure the student understands the criteria on which the evaluation is based. Assign a point value to each criterion and convert the total points to a percentage for grading.

Job Sheets—Be sure the student understands the criteria on which the evaluation is based. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher edition or student manual. Then observe the student performing the procedure. Rate both process and product.

> Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.
>
> Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. Complete the rating by assigning a point value to each criterion and by converting the point total to a percentage for grading. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Suggested Activities

Sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) which best fits your program needs.

Option A

4 - Skilled—Can perform job with no additional training.
3 - Moderately skilled—Has performed job during training program; limited additional training may be required.
2 - Limited skill—Has performed job during training program; additional training is required to develop skill.
1 - Unskilled—Is familiar with process, but is unable to perform job.

Option B

Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

Lighting
Unit 6

Answers to Assignment Sheet 1

A. 410-78
B. 410-67(c)
C. 700-20
D. 410-4
E. 410-83
F. 410-103

Lighting
Unit 6

Answers to Written Test

1.

a.	9	f.	7	k.	10	p.	3
b.	14	g.	15	l.	6	q.	13
c.	17	h.	18	m.	11	r.	4
d.	8	i.	16	n.	5		
e.	2	j.	12	o.	1		

2. a. Incandescent
   b. Fluorescent
   c. High intensity discharge (HID)

3. b, c

4. a. Color
   b. Phosphor
   c. Recessed double contact
   d. Preheat
   e. Stabilize

5. a. Mercury
   b. Mercury, metal halide
   c. Cooling
   d. Lumens-per-watt

6. a. $\text{Footcandles} = \dfrac{\text{Lumens on a Surface}}{\text{Area of Surface in Square Feet}}$
   b. F = 12.57 × I LM
   c. Photometer

7. a. 0.093
   b. ±7½%

8. a, d

Lighting
Unit 6

Written Test

Name ______________________________ Score ______________

1. Match the terms on the right with their correct definitions.

______a. Green lamp
______b. Light activated switch
______c. White lamp
______d. Footcandles
______e. Transformer used in lighting circuits
______f. Electric discharge lighting
______g. Instrument used to determine lumens
______h. Warm white lamp
______i. Coating inside a fluorescent bulb that determines the color of light
______j. A unit of light emitted from a point light source of one candle through a unit solid angle
______k. High intensity discharge
______l. Daylight lamp
______m. Consists of a filament which is a highly refractory conductor mounted in a transparent or translucent glass bulb
______n. Cool white lamp
______o. Blue lamp
______p. Coiled coil or triple coil tungsten wire at each end of lamp which is coated with material that emits electrons
______q. Pink lamp
______r. The square root of the ratio of the power reflected from a surface to the power incident of the same surface

1. B
2. Ballast
3. Cathode
4. Coefficient
5. CW
6. D
7. Fluorescent lighting
8. FC
9. G
10. HID
11. Incandescent lighting
12. Lumen
13. PK
14. Photocell
15. Photometer
16. Phosphor
17. W
18. WW

Written Test

2. List the three basic types of lighting.

   a. ____________________

   b. ____________________

   c. ____________________

3. Select true statements concerning characteristics of incandescent lighting by placing an "X" in the blank preceding each true statement.

   ______a. Incandescent lamps have the highest efficiency rating of any lamps and are the most popular type because of the low cost.

   ______b. Incandescent lamps come in many different sizes and shapes.

   ______c. Incandescent lamps have different bases.

4. Complete the following statements concerning characteristics of fluorescent lighting.

   a. Classification of fluorescent lamps is determined by the type, length or wattages, shape and ______________.

   b. The color of a fluorescent lamp depends on the ______________ used inside the lamp.

   c. There are four types of contacts found on tube bases of fluorescent lamps: single pin, bi-pin, four pin and ______________.

   d. There are three types of fluorescent tubes: ______________, rapid-start, and instant-start.

   e. The ballast is necessary to start the tube and to ______________ the current flow.

5. Complete the following statements concerning characteristics of high intensity discharge lamps.

   a. There are four basic types of HID lamps used in the lighting industry: ______________, metal halide, high pressure sodium, and low pressure sodium.

   b. ______________ and ______________ lamps have an additional electrode to assist lamp starting while others have no starting electrodes.

   c. When power is lost, HID lighting goes through a ______________ period before coming back on.

   d. HID lighting provides greater ______________ for the cost of operation.

Written Test

6. List three methods of calculating light.

   (Hint: Two methods use formulas to calculate light.)

   a. ____

   b. ____

   c. ____

7. Complete the following statements concerning calculating branch circuits and voltage by circling the numbers which best complete each statement.

   a. When calculating branch circuits for lighting loads of not less than that specified in *NEC* Table 220-3(b), the minimum lighting load for each square foot is (0.039, 0.093) square meter of floor area.

   b. Ballasts should operate within (±7½%, ±5½%) of rated voltage.

8. Select true statements concerning switching systems by placing an "X" in the blank preceding each true statement.

   ______a. Switches, photocells, and magnetic lighting contactors may be used to control lighting circuits.

   ______b. A photocell is a switch activated by light or motion.

   ______c. Lighting contactors are used when photocells and switches control the lighting amperage.

   ______d. Switches and dimmers may be used on fluorescent and HID lighting.

***Permission to duplicate this test is granted.**

Lighting
Unit 6

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Assignment Sheet 1—Locate Articles in the *NEC* Concerning Lighting Requirements Rating ______

Comments: ____

____

Job Sheet 1—Change a Two-Lamp Ballast in a Fluorescent Fixture Rating ______

Comments: ____

____

Job Sheet 2—Change Sockets in a Fluorescent Fixture Rating ______

Comments: ____

____

Job Sheet 3—Change an HID Ballast Rating ______

Comments: ____

____

Job Sheet 4—Change a Quartz Lamp Rating ______

Comments: ____

____

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ____

____

Teacher Signature ______________________________ Date __________

Student Signature ______________________________ Date __________

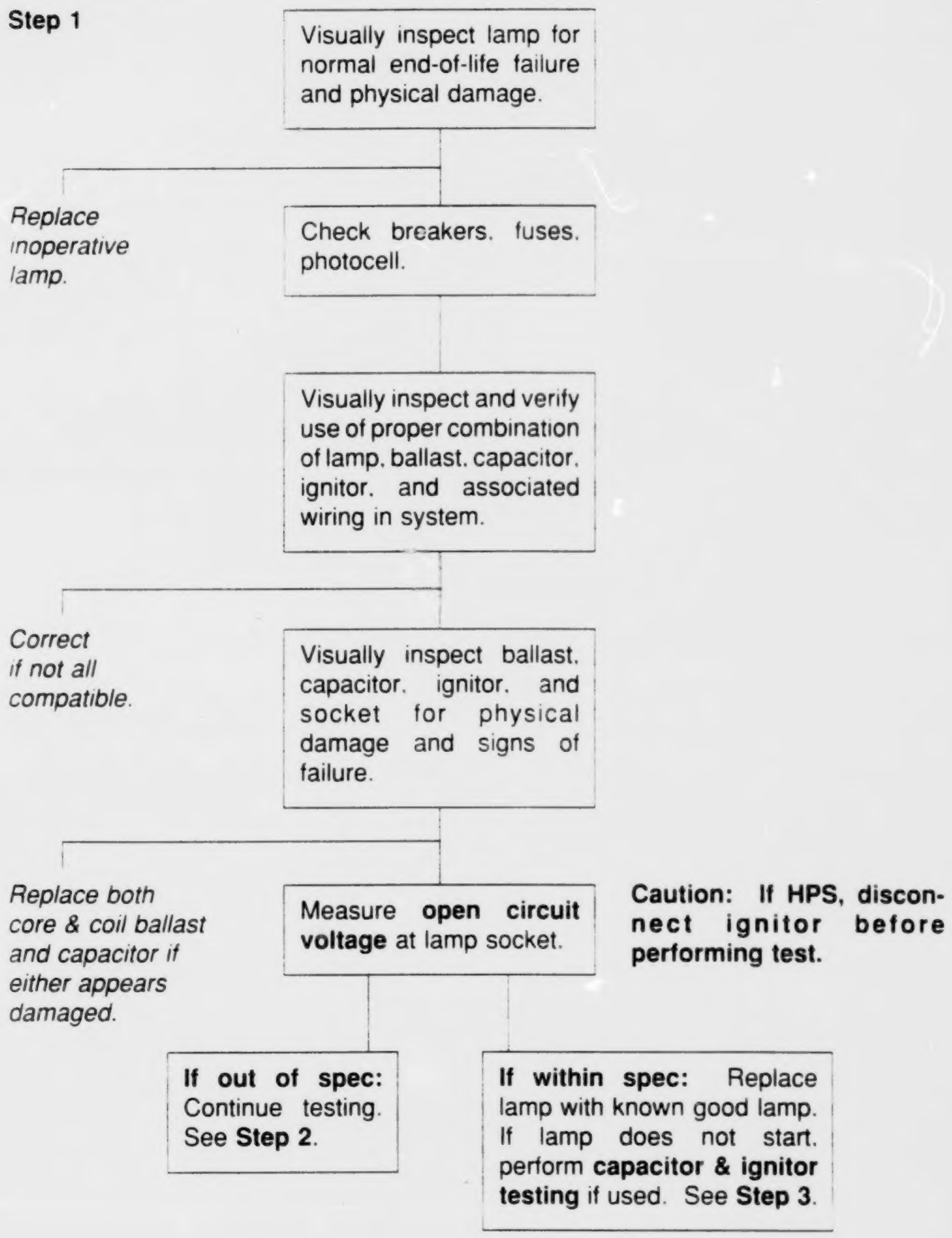
***Permission to duplicate this form is granted.**

Lighting
Unit 6

Teacher Supplement 1—Troubleshooting Procedures

A. Lamp will not start

Step 1



Visually inspect lamp for normal end-of-life failure and physical damage.

Replace inoperative lamp.

Check breakers, fuses, photocell.

Visually inspect and verify use of proper combination of lamp, ballast, capacitor, ignitor, and associated wiring in system.

Correct if not all compatible.

Visually inspect ballast, capacitor, ignitor, and socket for physical damage and signs of failure.

Replace both core & coil ballast and capacitor if either appears damaged.

Measure **open circuit voltage** at lamp socket.

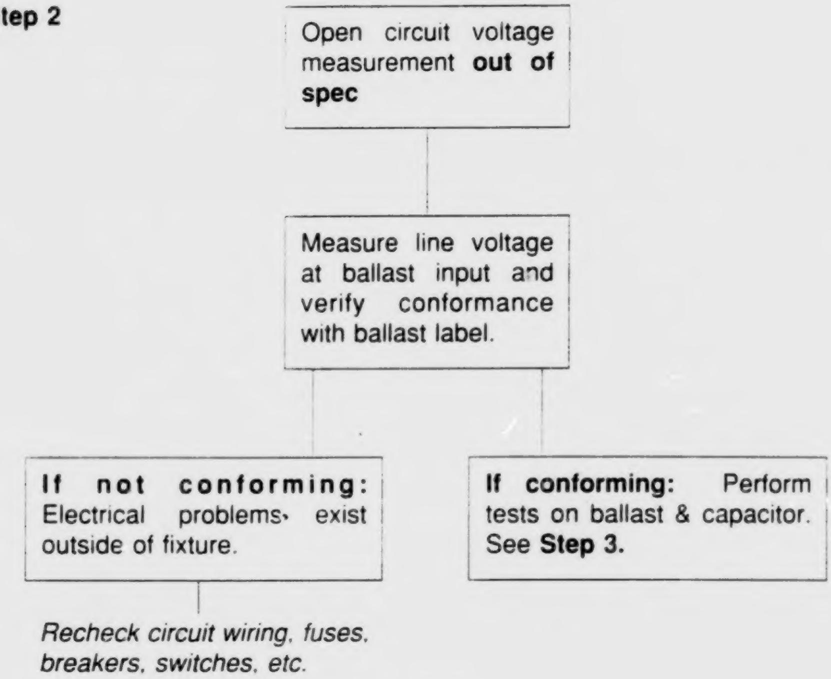
Caution: If HPS, disconnect ignitor before performing test.

If out of spec: Continue testing. See **Step 2**.

If within spec: Replace lamp with known good lamp. If lamp does not start, perform **capacitor & ignitor testing** if used. See **Step 3**.

Teacher Supplement 1

Step 2



Open circuit voltage measurement **out of spec**

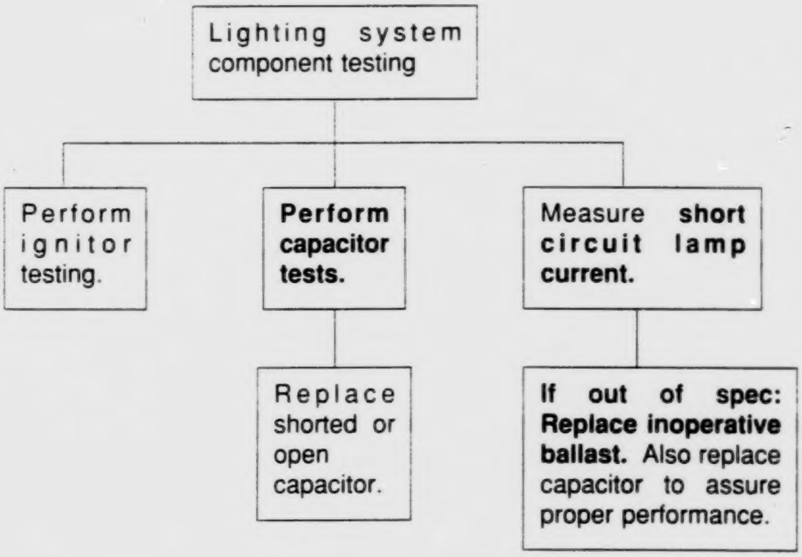
Measure line voltage at ballast input and verify conformance with ballast label.

If not conforming: Electrical problems exist outside of fixture.

Recheck circuit wiring, fuses, breakers, switches, etc.

If conforming: Perform tests on ballast & capacitor. See **Step 3.**

Step 3



Lighting system component testing

Perform ignitor testing.

Perform capacitor tests.

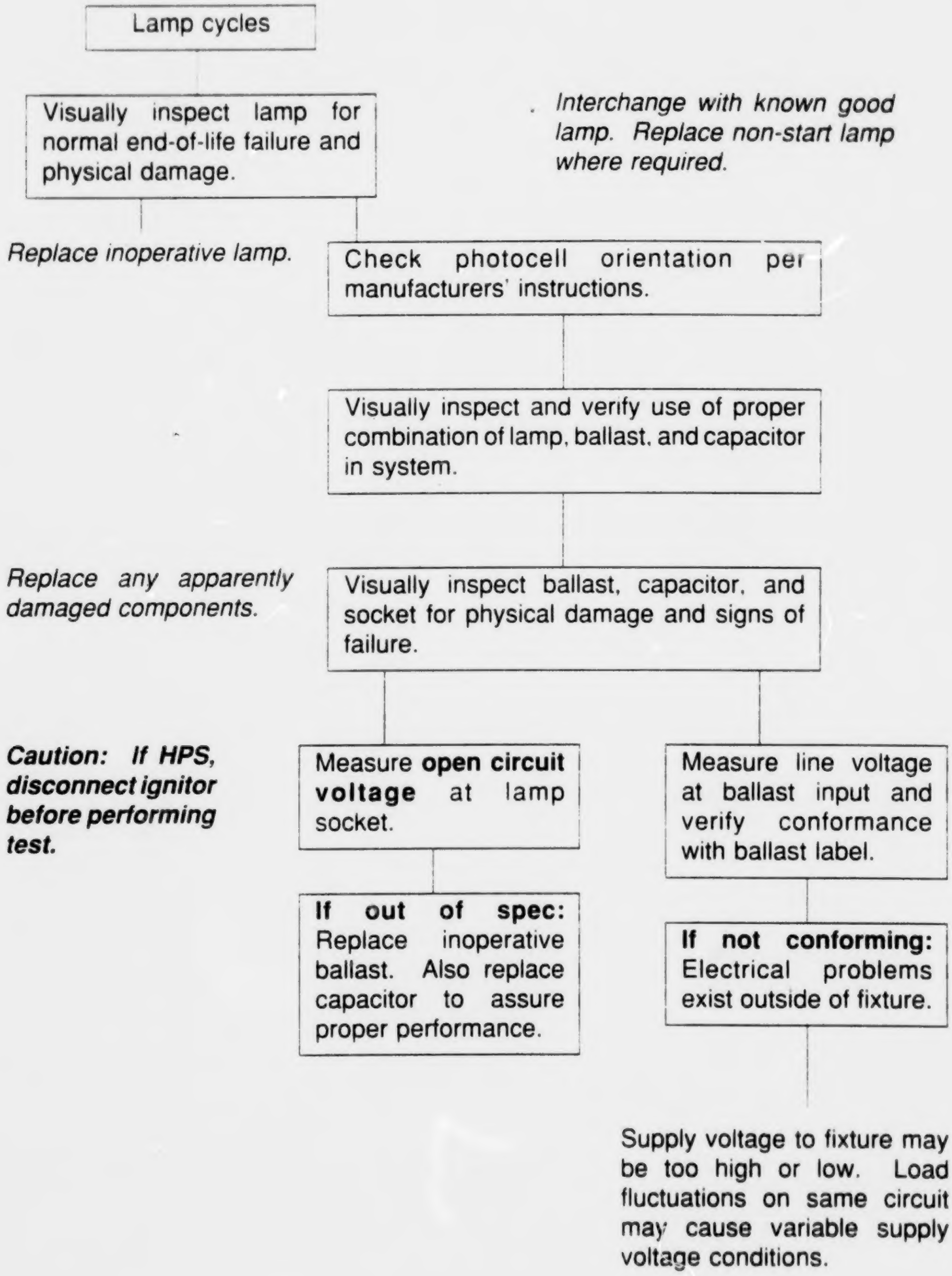
Replace shorted or open capacitor.

Measure **short circuit lamp current.**

If out of spec: Replace inoperative ballast. Also replace capacitor to assure proper performance.

Teacher Supplement 1

B. Lamp cycles



Lamp cycles

Visually inspect lamp for normal end-of-life failure and physical damage.

Interchange with known good lamp. Replace non-start lamp where required.

Replace inoperative lamp.

Check photocell orientation per manufacturers' instructions.

Visually inspect and verify use of proper combination of lamp, ballast, and capacitor in system.

Replace any apparently damaged components.

Visually inspect ballast, capacitor, and socket for physical damage and signs of failure.

Caution: If HPS, disconnect ignitor before performing test.

Measure **open circuit voltage** at lamp socket.

If out of spec: Replace inoperative ballast. Also replace capacitor to assure proper performance.

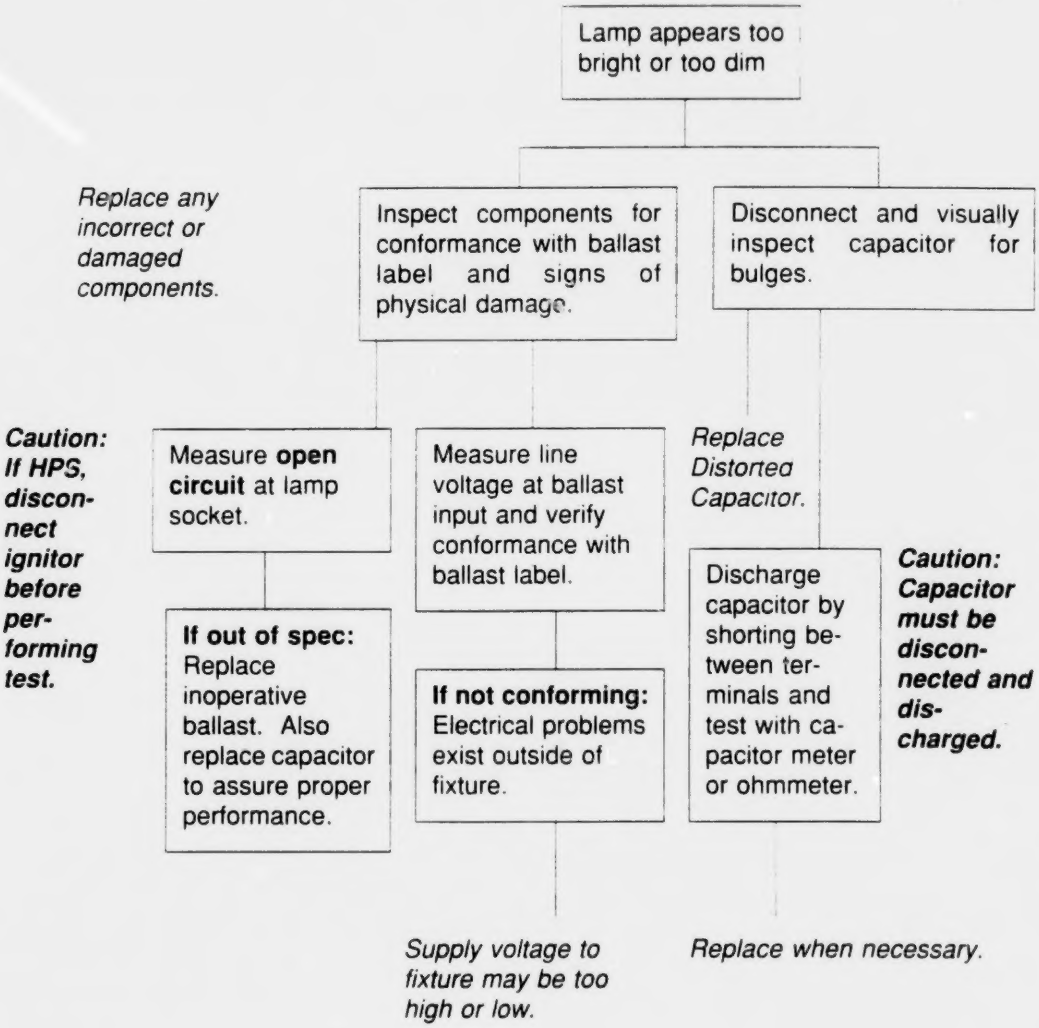
Measure line voltage at ballast input and verify conformance with ballast label.

If not conforming: Electrical problems exist outside of fixture.

Supply voltage to fixture may be too high or low. Load fluctuations on same circuit may cause variable supply voltage conditions.

Teacher Supplement 1

C. Lamp too bright or dim



Lamp appears too bright or too dim

Inspect components for conformance with ballast label and signs of physical damage.

Replace any incorrect or damaged components.

Disconnect and visually inspect capacitor for bulges.

Caution: If HPS, disconnect ignitor before performing test.

Measure **open circuit** at lamp socket.

If out of spec: Replace inoperative ballast. Also replace capacitor to assure proper performance.

Measure line voltage at ballast input and verify conformance with ballast label.

If not conforming: Electrical problems exist outside of fixture.

Supply voltage to fixture may be too high or low.

Replace Distorted Capacitor.

Discharge capacitor by shorting between terminals and test with capacitor meter or ohmmeter.

Caution: Capacitor must be disconnected and discharged.

Replace when necessary.

Courtesy of Advance Transformer Company.

Lighting
Unit 6

Information Sheet

1. **Terms and definitions**

   a. **B** — Blue lamp

   b. **Ballast** — Transformer used in lighting circuits

   c. **Cathode** — Coiled coil or triple coil tungsten wire at each end of lamp which is coated with material that emits electrons

   d. **Coefficient** — The square root of the ratio of the power reflected from a surface to the power incident of the same surface

   e. **CW** — Cool white lamp

   f. **D** — Daylight lamp

   g. **Fluorescent lighting** — Electric discharge lighting

   h. **FC** — Footcandles

   i. **G** — Green lamp

   j. **HID** — High intensity discharge

   k. **Incandescent lighting** — Consists of a filament which is a highly refractory conductor mounted in a transparent or translucent glass bulb

   l. **Lumen** — A unit of light emitted from a point light source of one candle through a unit solid angle

   m. **PK** — Pink lamp

   n. **Photocell** — Light activated switch

   o. **Photometer** — Instrument used to determine lumens

   p. **Phosphor** — Coating inside a fluorescent bulb that determines the color of light

   q. **W** — White lamp

   r. **WW** — Warm white lamp

Information Sheet

2. **Basic types of lighting**

   a. Incandescent

   b. Fluorescent

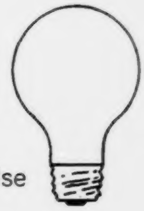
   c. High intensity discharge (HID)

3. **Characteristics of incandescent lighting**

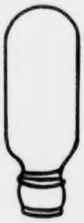
   a. Incandescent lamps each have the lowest efficiency rating of any lamps, but are the most popular type used because of the low cost.

   b. Incandescent lamps come in many different sizes and shapes.

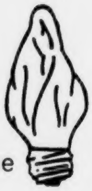
   Examples:



General Use



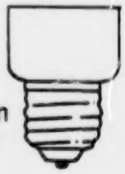
Tube



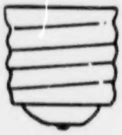
Flame

   c. Incandescent lamps have different bases.

   Examples:



Medium Skirted



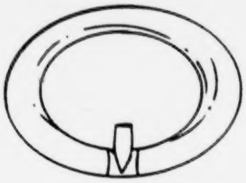
Mogul

Information Sheet

4. Characteristics of fluorescent lighting

a. Classifications of fluorescent lamps is determined by the type, length or wattage, shape and color.

Example:

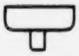


b. The color of a fluorescent lamp depends on the phosphor used inside the lamp.

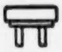
Note: Different colors are usually marked on the lamp as D—daylight, W—white, CW—cool white, WW—warm white, B—blue, PK—pink, and G—green.

c. There are four types of contacts found on tube bases of fluorescent lamps:

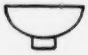
Examples:



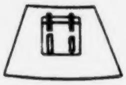
Single Pin



Bi-Pin



Recessed Double Contact Pin



Four Pin

d. There are three types of fluorescent tubes: preheat, rapid-start, and instant-start.

e. The ballast is necessary to start the tube and to stabilize the current flow. Without it, the fluorescent light would quickly burn itself out.

Information Sheet

5. Characteristics of high intensity discharge (HID) lamps

a. There are four basic types of HID lamps used in the lighting industry: mercury, metal halide, high pressure sodium, and low pressure sodium.

b. Mercury and metal halide lamps have an additional electrode to assist lamp starting while high pressure sodium, low pressure sodium, and some newer metal halide lamps have no starting electrodes.

c. There are disadvantages and advantages when using high intensity discharge lighting.

- Disadvantages — HID lighting takes longer to reach full output. When power is lost, HID lighting goes through a cooling period before coming back on. Emergency back-up lighting is generally used when an HID system is in operation.

Light Source	Warm-Up Time	Restrike Time
Mercury Vapor	5-7 minutes	3-6 minutes
Metal Halide	2-5 minutes	10-20 minutes
High Pressure Sodium	3-4 minutes	½-1 minute
Low Pressure Sodium	7-10 minutes	3-12 minutes

- Advantages — HID lighting provides greater lumens per watt for the cost of operation. HID lighting is less expensive to operate than any other source of lighting. HID lighting also has fewer maintenance problems.

6. Methods of calculating light

a. Footcandles may be calculated by the following formula when the lumens and square feet are known.

Note: The intensity of light at a distance from the source is expressed in footcandles or in lumens.

$$\text{Footcandles} = \frac{\text{Lumens on a Surface}}{\text{Area of Surface in Square Feet}}$$

b. To obtain the output of a light source in lumens when spherical candle power is known, use the formula

$F = 12.57 \times I$ LM

c. A photometer is an instrument used in determining the luminous intensity, in candles, of a light source.

Information Sheet

7. Calculating branch circuits and voltage

a. When calculating branch circuits for lighting loads of not less than that specified in *NEC* Table 220-3(b), the minimum lighting load for each square foot is 0.093 square meters of floor area.

b. If line voltage is higher or lower than that for which the ballast was designed, this condition can affect lamp life, ballast life, and lamp light output. Ballasts should operate within ±7½% of rated voltage.

8. Switching systems

a. Switches, photocells, and magnetic lighting contactors may be used to control lighting circuits.

b. Switches may be used for controlling lighting circuits when the amperes are within the rating of the switch.

c. A photocell is a switch activated by light or sunlight. It may be used for controlling lights within its ampacity or can control a lighting contactor.

d. Lighting contactors are used when photocells and switches cannot control the lighting amperage. Photocells and switches may then be used as control circuits for a lighting contactor.

e. Switches and dimmers may be used on fluorescent and HID lighting. The output of fluorescent or HID lamps can be adjusted by holding a constant voltage on the cathodes and controlling the current passing through the lamp. Thyrations, silicon-controlled rectifiers, and autotransformers can provide this type of control.

Lighting
Unit 6

Assignment Sheet 1—Locate Articles in the *NEC* Concerning Lighting Requirements

Name ______________________________ Overall Rating __________

Evaluation Criteria	**Rating**
Correct use of *NEC* demonstrated	______
Correct answers obtained	______

Directions: List *NEC* article numbers that pertain to the following lighting conditions. The above criteria will be used to evaluate your performance.

A. Autotransformers ______________________________

B. Tap conductors ______________________________

C. Emergency lighting switch requirements ______________________________

D. Wet and damp locations ______________________________

E. Transformer ratings ______________________________

F. Track lighting ______________________________

Lighting
Unit 6

Job Sheet 1—Change a Two-Lamp Ballast in a Fluorescent Fixture

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Installed ballast properly	______
Connections tight	______
Installed lamps correctly	______
Fixture works	______
Demonstrated good workmanship	______
Complied to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
Eight wire nuts
Two-lamp ballast
Eye protection

B. Procedure

☐ 1. Observe safety rules throughout this procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Put on eye protection.

☐ 4. Disconnect the power.

☐ 5. Remove the lamps.

Job Sheet 1

☐ 6. Remove the ballast cover from the fixture.

☐ 7. Cut wires 6″ from ends of socket.

Note: Do not cut wires less than 6″ as this will void the warranty.

☐ 8. Remove the old ballast.

☐ 9. Install the new ballast.

Note: Check the warranty date on the ballast. Most ballasts are under warranty for one year.

☐ 10. Re-connect conductors back by color.

☐ 11. Re-connect the power.

☐ 12. Install the ballast cover plate.

☐ 13. Install the lamps.

☐ 14. Apply power and check the fixture operation.

☐ 15. Return tools and materials to proper storage.

☐ 16. Clean the work area.

Evaluator's comments: ____

____

____

Lighting
Unit 6

Job Sheet 2—Change Sockets in a Fluorescent Fixture

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Wired sockets correctly	______
Connections tight	______
Installed lamps correctly	______
Fixture works	______
Demonstrated good workmanship	______
Complied to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
Eight two-pin fixture sockets
Eye protection

B. Procedure

☐ 1. Observe safety rules throughout the procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Put on eye protection.

☐ 4. Disconnect the power.

☐ 5. Remove the lamps.

Job Sheet 2

☐ 6. Remove the ballast cover from the fixture.

☐ 7. Remove the socket end plate.

☐ 8. Remove one socket at a time and replace with a new socket.

☐ 9. Install the socket end plate.

☐ 10. Re-connect the power.

☐ 11. Install the ballast cover plate.

☐ 12. Install the lamps.

☐ 13. Apply power and check fixture operation.

☐ 14. Return tools and materials to proper storage.

☐ 15. Clean the work area.

Evaluator's comments: ______________________________

____

____

Lighting
Unit 6

Job Sheet 3—Change an HID Ballast

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Voltages match	______
Installed ballast correctly	______
Fixture works	______
Demonstrated good workmanship	______
Complied to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
HID ballast
12 yellow wire outs

B. Procedure

☐ 1. Observe safety rules throughout the procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Disconnect the power.

☐ 4. Remove the cover from the fixture.

☐ 5. Check the old ballast voltage to the new ballast.

☐ 6. Cut the old ballast wiring.

Job Sheet 3

☐ 7. Remove the old ballast.

☐ 8. Install the new ballast.

☐ 9. Connect the new ballast.

☐ 10. Install the cover plate

☐ 11. Apply power and check fixture operation.

☐ 12. Return tools and materials to proper storage.

☐ 13. Clean the work area.

Evaluator's comments: ______________________________

____

____

Lighting
Unit 6

Job Sheet 4—Change a Quartz Lamp

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Installed new lamp correctly	______
Fixture works	______
Demonstrated good workmanship	______
Complied to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
Paper towels or clean rags
Quartz lamp

B. Procedure

☐ 1. Observe safety rules throughout the procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Disconnect the power.

☐ 4. Open the cover to the fixture.

☐ 5. Remove the old lamp.

☐ 6. Install the new lamp using a paper towel or rag.

☐ 7. Close the cover to the fixture.

Job Sheet 4

☐ 8. Apply power and check fixture operation.

☐ 9. Return tools and materials to proper storage.

☐ 10. Clean the work area.

Evaluator's comments: ____

____

____

Motors and Controllers
Unit 7

Objective Sheet

Unit Objective

After completing this unit, the student should be able to identify and test or wire common contactors, starters and motors. The student should demonstrate these competencies by completing the assignment and job sheets, and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to motors and controllers with their correct definitions.
2. Discuss direct current motor theory of operation.
3. List types of DC motors.
4. Discuss single-phase motor theory of operation.
5. List types of single-phase motors.
6. Discuss three-phase motor theory of operation.
7. List types of three-phase motors.
8. State the procedure for reversing rotation of a three-phase motor.
9. Select from a list typical supply voltages for three-phase motors.
10. Identify schematics and terminal connections for delta- and wye-wound three-phase motors.
11. Match motor problems with their typical symptoms.
12. Match remedies with the correct symptoms of motor problems.
13. Complete safety rules to observe when working around motors.
14. List types of contactors.
15. Identify parts of a manual contactor.

Objective Sheet

16. Select from a list electrical devices or circuits controlled by contactors.
17. Name types of motor starters.
18. Identify types of magnetic motor starters.
19. List uses of magnetic motor starters.
20. Compare parts in magnetic contactors with parts in magnetic motor starters.
21. Complete statements concerning reasons a contactor cannot be used to control a motor.
22. State purposes of a coil assembly.
23. Identify parts of a coil assembly.
24. Interpret nameplate information. (Assignment Sheet 1)
25. Describe remedies for common motor problems. (Assignment Sheet 2)
26. Use the *National Electrical Code* to answer questions about motor control circuits. (Assignment Sheet 3)
27. Distinguish between motor starters and contactors. (Assignment Sheet 4)
28. Answer questions about uses of contactors and motor starters. (Assignment Sheet 5)
29. Disassemble, inspect, and clean a motor. (Job Sheet 1)
30. Identify run, common, and start terminals on hermetically sealed motors. (Job Sheet 2)
31. Test capacitors with an ohmmeter. (Job Sheet 3)
32. Wire a three-phase motor for dual voltages. (Job Sheet 4)
33. Perform maintenance on a magnetic motor starter or contactor. (Job Sheet 5)

Motors and Controllers
Unit 7

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.

2. Review Teaching Suggestions section that follows. Plan for classroom activities.

3. Plan for students with special needs.

4. Make transparencies from the transparency masters included with this unit. These appear in the teacher edition only and are designed to be used with the following objectives:

   TM 1—Magnetic Poles in an Electric Motor (Objective 2)
   TM 2—Polyphase Magnetism (Objective 2)
   TM 3—Squirrel Cage Rotor (Objective 6)
   TM 4—Delta-Wound Motor (Objective 6)
   TM 5—Wye-Wound Motor (Single Speed) (Objective 6)
   TM 6—Three-Phase Motor Windings (Objective 6)
   TM 7—Dual Voltage Three-Phase Motor Showing Possible Six, Nine, and Ten Leads (Objective 6)
   TM 8—Dual Voltage Three-Phase Motor Showing Possible Twelve Leads (Objective 10)
   TM 9—Types of Magnetic Contactor Assemblies (Objective 15)

5. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.

6. Develop teaching plan. Adjust for different learning styles.

7. Make copies of Unit Evaluation Form.

Delivery and Application

8. Provide students with unit of instruction.

9. Discuss unit and specific objectives.

10. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.

11. Discuss the assignment and job sheets. Review criteria for evaluation of these activities.

Suggested Activities

Evaluation

12. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.
13. Make copies of the written test. Add or modify test items as needed.
14. Give written test.
15. Record assignment sheet ratings, job sheet ratings, and written test scores on the Unit Evaluation Form. Add any additional assignments or supplemental activities that should be part of the unit evaluation.
16. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Visit a motor winding shop. Discuss observations with the class.
2. Visit a local industry and view types of motors and controllers used. Encourage students to question why certain types were chosen for a particular job. Skill area: **oral communication**.
3. Invite a local maintenance or industrial electrician to speak on the importance of controllers and motors. Encourage note taking and questions. Skill areas: **listening** and **oral communication**.

Resources Used in Developing This Unit

1. Adams, James and Gordon Rockmaker. *Industrial Electricity: Principles and Practices*, 3rd Ed. New York: McGraw-Hill Book Company, 1985.
2. Kaltwasser, Stan and Gary Flowers. *Commercial and Industrial Wiring*. Stillwater, OK: Mid-America Vocational and Curriculum Consortium, 1988.
3. *National Electrical Code 1993*. Quincy, MA: National Fire Protection Association, 1992.
4. Teague, Cash and Garner Pewewardy. *Industrial Electricity: In-Plant Distribution*. Stillwater, OK: Oklahoma Curriculum and Instructional Materials Center, 1984.

Suggested Activities

Suggested Supplemental Resources

1. Croft, Terrell and Wilford I. Summers. *American Electrician's Handbook*. 11th Ed. New York: McGraw-Hill Book Company, 1987.

2. Earley, Mark W., John M. Caloggero and Richard H. Murray. *NEC Handbook 1993*. Quincy, MA: National Fire Protection Association, 1992.

3. O'Riley, Ronald P. *Illustrated Changes in the 1993 National Electrical Code*. Albany, NY: Delmar Publishers, Inc., 1993.

Instructions for Evaluating Student Performance

Assignment Sheets—Be sure the student understands the criteria on which the evaluation is based. Assign a point value to each criterion and convert the total points to a percentage for grading.

Job Sheets—Be sure the student understands the criteria on which the evaluation is based. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher edition or student manual. Then observe the student performing the procedure. Rate both process and product.

> Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.
>
> Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. Complete the rating by assigning a point value to each criterion and by converting the point total to a percentage for grading. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Suggested Activities

Sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) which best fits your program needs.

Option A

4 - Skilled—Can perform job with no additional training.

3 - Moderately skilled—Has performed job during training program; limited additional training may be required.

2 - Limited skill—Has performed job during training program; additional training is required to develop skill.

1 - Unskilled—Is familiar with process, but is unable to perform job.

Option B

Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

Motors and Controllers
Unit 7

Answers to Assignment Sheets

Assignment Sheet 1 — Answers will vary according to motor selected.

Assignment Sheet 2

A.
1. Check supply voltage.
2. Check motor wiring with ohmmeter.
3. Remove load from motor and try to start.
4. Move motor shaft by hand to check for end play and bearing tightness.

B.
1. Clean motor.
2. Adjust belt tension.
3. Check full load amperage.
4. Check for correct voltage.
5. Check for loose bearings.
6. Check for tight bearings.
7. Check pulley alignment.
8. Check for bent shaft.

C.
1. Replace out of balance pulley.
2. Remove pulley and check straightness of shaft.
3. Tighten motor accessories and mounting.
4. Align drive pulley and driven pulley.
5. Replace bearings.
6. Clean motor.
7. Check for out-of-round motor.

D.
1. Use recommended motor bearing oil.
2. Put clean oil in reservoir.
3. Clean excessive grease buildup.
4. Adjust belt.
5. Move shaft by hand to check end and side play.
6. Replace rough or worn bearings.
7. Remove pulley and check for bent shaft.
8. Align drive pulley with driven pulley.

Answers to Assignment Sheets

Assignment Sheet 3

A. 430-72(b), 430-31 (Also Article 240)
B. 1. Conductors that do not leave enclosure
   2. Conductors supplied by transformer

   Note: These exceptions are found in 430-72(b) 1-4.

C. No.
D. Must be protected by raceway or enclosure
E. At time motor circuit is disconnected
F. A circuit designed for signaling and control of a motor starter
G. Conduit or raceway
H. A disconnecting means shall be located in sight from the controller location

Assignment Sheet 4

A. Contactor
B. Motor starter
C. Contactor
D. Contactor
E. Motor starter
F. Contactor
G. Contactor
H. A, C, D, F, G; contactors do not have thermal overloads (heaters), reset button, or overload contacts
I. B, E; motor starters do have thermal overloads (heaters), reset button, or overload contacts

Assignment Sheet 5

A. 1. Motor starter
   2. Contactor
B. 1. Lighting loads
   2. Heaters
   3. Transformers
   4. Capacitors
   5. Power circuits
C. 1. Starting motors
   2. Reversing motors
   3. Braking motors to stop
   4. Controlling speed of motors
D. 1. Contactors do not provide running overload protection for motors.
   2. Contactors are not designed for high inrush current for motor starting.
   3. Contactors do not contain sets of overload contacts.

Motors and Controllers
Unit 7

Answers to Written Test

1.
   a. 13
   b. 6
   c. 10
   d. 1
   e. 8
   f. 12
   g. 2
   h. 7
   i. 11
   j. 4
   k. 5
   l. 3
   m. 9

2.
   a. A magnetic field is produced at the face of the stationary poles.
   b. A magnetic field is produced in the armature windings.
   c. The fields repel each other causing the armature to rotate.

3.
   a. Shunt motor
   b. Series motor
   c. Compound motor

4.
   a. The motor operates on a single wave form from a two-wire A/C system.
   b. A/C single phase current produces a varying magnetic field.

5.
   a. Shaded pole
   b. Split phase
   c. Capacitor
   d. Induction repulsion
   e. Series

6.
   a. Current in the stator produces a rotating magnetic field.
   b. Currents induced in the rotor create a magnetic field.
   c. The rotor turns, seeking an opposite pole.

7.
   a. Squirrel cage induction
   b. Wound rotor
   c. Synchronous

8. A three-phase motor is reversed by interchanging any two of the three supply lines anywhere between the motor and the source of supply.

9. b, c

10.
   a. Delta-wound 9-lead high voltage
   b. Delta-wound 9-lead low voltage
   c. Wye-wound 9-lead high voltage
   d. Wye-wound 9-lead low voltage

Answers to Written Test

11. a. 7, 12, 13, 14, 15
    b. 3, 6, 9, 12
    c. 2, 5, 6, 8, 11, 12
    d. 1, 2, 4, 7, 10, 14, 15

12. a. 6, 8
    b. 1, 3
    c. 2, 3, 4
    d. 1, 4, 5, 7

13. a. Danger
    b. Overload
    c. Protective
    d. Wires
    e. Tag, lock
    f. Ground

14. a. Manual
    b. Magnetic

15. a. Start/stop buttons
    b. Insulated operating mechanism enclosure
    c. Saddle clamp terminal for power input circuit
    d. Stationary contact
    e. Arc chutes
    f. Insulated contactor main frame
    g. Saddle clamp terminals for power output circuit
    h. Insulated T-frame assembly
    i. Moveable contacts
    j. Spring

16. b, c, d, f, g

17. a. Manual
    b. Magnetic

18. a. Starting
    b. Reversing

19. Any three of the following:

    a. Starting motors
    b. Reversing motors
    c. Braking motors to stop
    d. Controlling speed of motors

Answers to Written Test

20.		**Contactors**	**Starters**
	a.	No	Yes
	b.	Yes	Yes
	c.	No	Yes
	d.	Yes	Yes
	e.	No	Yes
	f.	Yes	Yes
	g.	Yes	Yes
	h.	Yes	Yes

21. a. Overload protection
    b. High inrush current
    c. Overload contacts

22. a. To change an electrical signal to a magnetic signal
    b. To activate the mechanical portion of the motor starter

23. a. Laminations
    b. Rivets
    c. Magnetic coil
    d. Armature
    e. Air gap
    f. Magnetic assembly
    g. Shading coil

Motors and Controllers
Unit 7

Written Test

Name ______________________________ Score ______________

1. Match the terms on the right with their correct definitions.

_____a. Three-phase circuit in which the windings are connected in the shape of a "Y"

_____b. Ratio of active power to apparent power

_____c. Device used to make or break a motor's power circuit

_____d. Partition between contacts to reduce electrical arcing

_____e. Single turn of conducting material mounted on the magnetic assembly face to produce out-of-phase magnetic force

_____f. Force that produces a rotating or twisting action

_____g. Portion of coil assembly moved by magnetism

_____h. Operated by a change in one electrical circuit to control a device in the same circuit or another circuit; used in control circuits

_____i. Device used to sense current draw in a circuit and open a control circuit when its rating is exceeded

_____j. Three-phase circuit in which the windings are connected in series to form a closed loop

1. Arc chute
2. Armature
3. Contactor
4. Delta
5. Dual voltage motor
6. Power factor
7. Relay
8. Shading coil
9. Single phasing
10. Starter
11. Thermal overloads
12. Torque
13. Wye

Written Test

_____k. Motor capable of being wired to run at two different voltages

_____l. Device used to make and break electrical power circuit

_____m. Loss of one phase of a three-phase system

2. Discuss direct current motor theory of operation.

a. ____

____

b. ____

____

c. ____

____

3. List three types of DC motors.

a. ____

b. ____

c. ____

4. Discuss single-phase motor theory of operation.

a. ____

____

b. ____

____

Written Test

5. List five types of single-phase motors.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

6. Discuss three-phase motor theory of operation.

   a. ______________________________

   ____

   b. ______________________________

   ____

   c. ______________________________

   ____

7. List three types of three-phase motors.

   a. ______________________________

   b. ______________________________

   c. ______________________________

8. State the procedure for reversing rotation of a three-phase motor.

   ____

   ____

   ____

Written Test

9. Select from the following list typical supply voltages for three-phase motors by placing an "X" in the blank preceding each correct answer.

______a. 360-volt three-phase delta

______b. 240-volt three-phase delta

______c. 208-volt three-phase wye

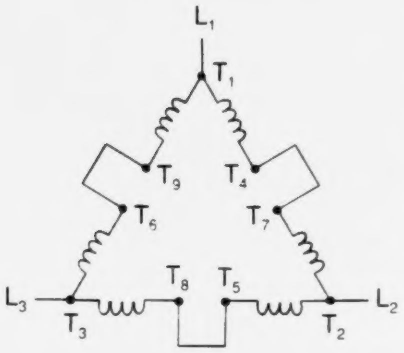
______d. 240-volt three-phase wye

______e. 480-volt three-phase wye

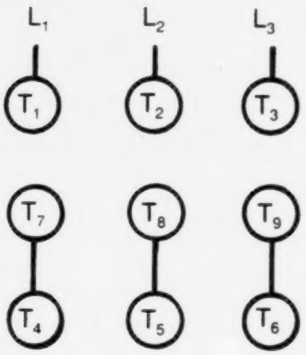
10. Identify schematics and terminal connections for delta- and wye-wound three-phase motors.

a. ____

Schematic Connection


L_1
T_1
T_9
T_4
T_6
T_7
T_8
T_5
L_3
T_3
T_2
L_2

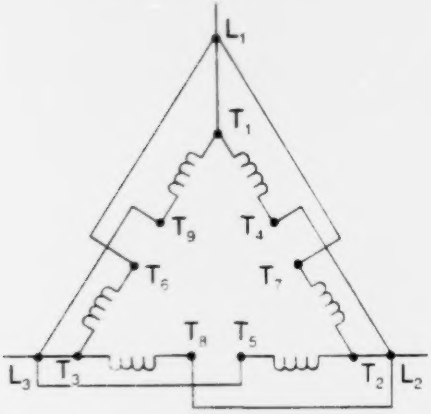
Terminal Connection


L_1
L_2
L_3
T_1
T_2
T_3
T_7
T_8
T_9
T_4
T_5
T_6

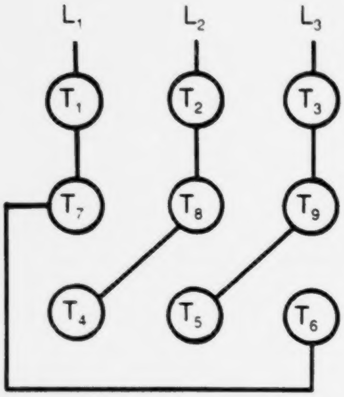
Written Test

b. ____

Schematic Connection

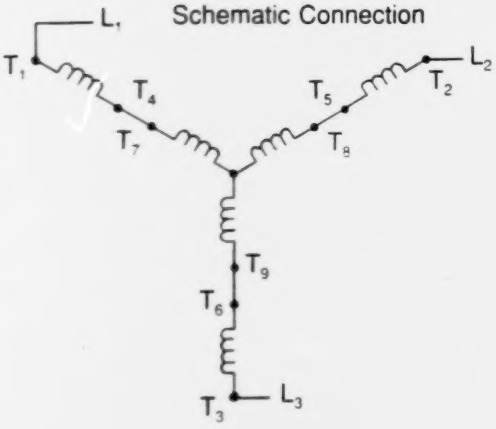

L_1
T_1
T_9
T_4
T_6
T_7
T_8
T_5
L_3
T_3
T_2
L_2

Terminal Connection

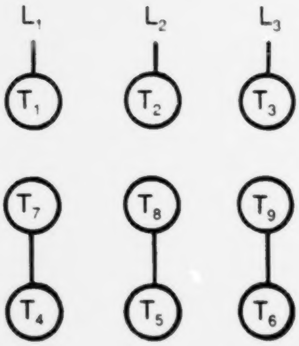

L_1
L_2
L_3
T_1
T_2
T_3
T_7
T_8
T_9
T_4
T_5
T_6

c. ____

Schematic Connection


L_1
T_1
T_4
T_7
T_5
T_8
T_2
L_2
T_9
T_6
T_3
L_3

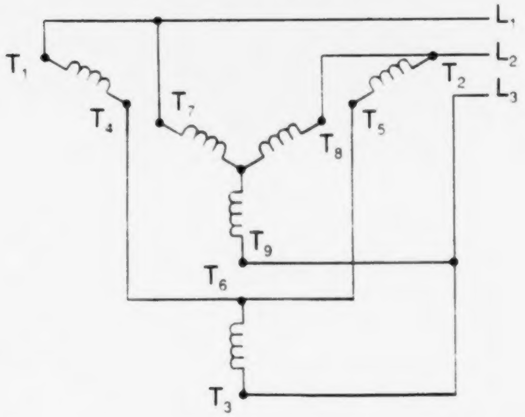
Terminal Connection


L_1
L_2
L_3
T_1
T_2
T_3
T_7
T_8
T_9
T_4
T_5
T_6

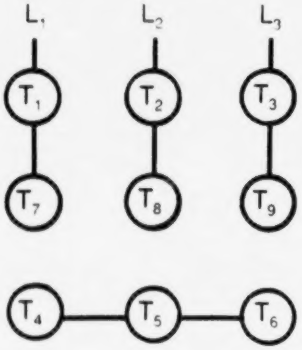
Written Test

d. ____

Schematic Connection



Terminal Connection



11. Match motor problems on the right with their typical symptoms.

Note: Blanks should contain more than one answer.

a. ____________ Failure to start

b. ____________ Excessive noise

c. ____________ Overheated bearings

d. ____________ Overheated motor

1. Obstruction of ventilating system
2. Lack of oil
3. Unbalanced parts
4. Overloading
5. Dirty oil
6. Bent shaft
7. Incorrect voltage
8. Excessive end thrust
9. Faulty alignment
10. High ambient temperature
11. Excessive grease or oil
12. Worn bearings
13. Blown fuse
14. Open overload
15. Excessive load

Written Test

12. Match remedies on the right with the correct symptoms of motor problems.

    a. ____________ Failure to start
    b. ____________ Excessive noise
    c. ____________ Overheated bearings
    d. ____________ Overheated motor

    1. Clean motor
    2. Put clean oil in reservoir
    3. Replace bearings
    4. Adjust belt tension
    5. Check for correct voltage
    6. Check supply voltage
    7. Check full load amperage
    8. Check motor wiring with ohmmeter

13. Complete the following safety rules to observe when working around motors.

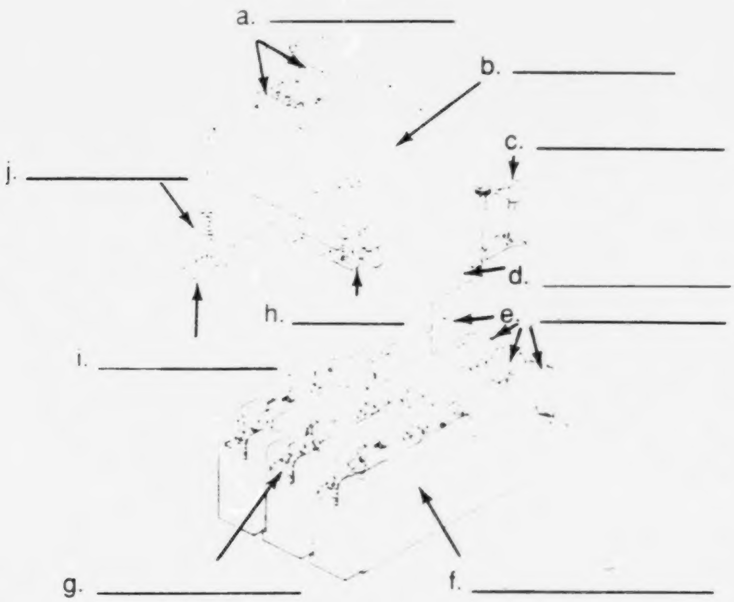
    a. Do not underestimate the __________________ of the circuit.
    b. Never install equipment that will __________________ the circuit.
    c. Never bypass __________________ devices.
    d. Protect all __________________ from physical and thermal hazards.
    e. __________________ and __________________ electrical disconnects when working on motors or motor circuits.
    f. __________________ all electric motor frames.

14. Name two types of contactors.

    a. ____
    b. ____

Written Test

15. Identify the parts of the manual contactor illustrated below.



16. Select from the following list electrical devices or circuits controlled by contactors by placing an "X" in the blank preceding each correct answer.

_____a. Starting buttons

_____b. Lighting loads

_____c. Heaters

_____d. Transformers

_____e. Overload contacts

_____f. Capacitors

_____g. Power circuits

Written Test

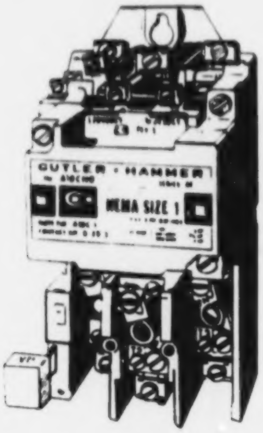
17. Name two types of motor starters.

a. ____

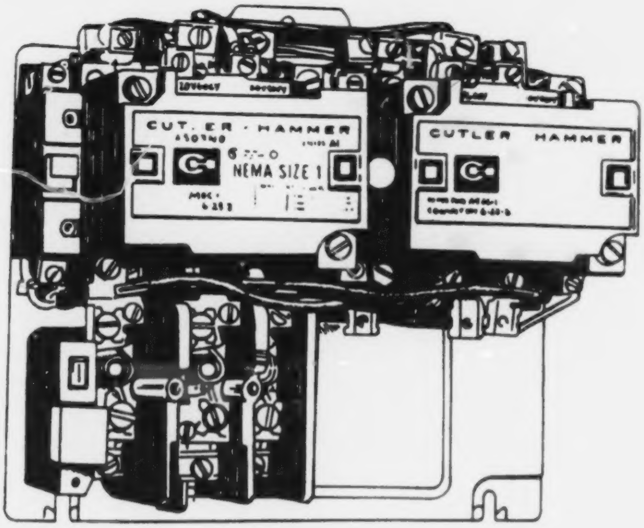
b. ____

18. Identify the types of magnetic motor starters illustrated below.

a. ____


CUTLER · HAMMER
NEMA SIZE 1

b. ____


CUTLER · HAMMER
NEMA SIZE 1
CUTLER HAMMER

Written Test

19. List three uses of magnetic motor starters.

a. ______________________________

b. ______________________________

c. ______________________________

20. Compare parts in magnetic contactors with parts in magnetic motor starters by writing "yes" or "no" in the correct column for each part.

	Parts	Contactors	Motor Starters
a.	Overload contact		
b.	Line terminals		
c.	Reset button		
d.	Power contacts		
e.	Thermal overload (heater)		
f.	Load terminals		
g.	Coil		
h.	Holding contacts		

21. Complete the following statements concerning reasons a contactor cannot be used to control a motor.

a. A contactor does not provide running ______________ ______________ for the motor.

b. A contactor is not designed for ______________ ______________ ______________ for motor starting.

c. A contactor does not contain a set of ______________ ______________.

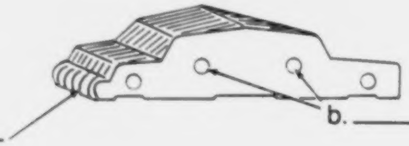
22. State the purposes of a coil assembly.

a. ______________________________

b. ______________________________

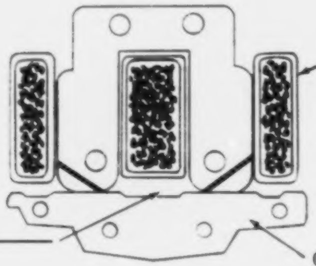
Written Test

23. Identify the parts of the coil assembly illustrated below.



a. ____________

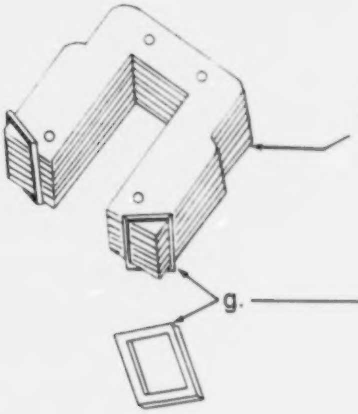
b. ____________



c. ____________

e. ____________

d. ____________



f. ____________

g. ____________

*Permission to duplicate this test is granted.

Motors and Controllers
Unit 7

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Assignment Sheet 1—Interpret Nameplate Information Rating ______

Comments: ____

____

Assignment Sheet 2—Describe Remedies for Common Motor Problems Rating ______

Comments: ____

____

Assignment Sheet 3—Use the *National Electrical Code* to Answer Questions About Motor Control Circuits Rating ______

Comments: ____

____

Assignment Sheet 4—Distinguish Between Motor Starters and Contactors Rating ______

Comments: ____

____

Assignment Sheet 5—Answer Questions About Uses of Contactors and Motor Starters Rating ______

Comments: ____

____

Job Sheet 1—Disassemble, Inspect, and Clean a Motor Rating ______

Comments: ____

____

Job Sheet 2—Identify Run, Common, and Start Terminals on Hermetically Sealed Motors Rating ______

Comments: ____

____

Unit Evaluation Form

Job Sheet 3—Test Capacitors With an Ohmmeter Rating ______

Comments: ______________________________

Job Sheet 4—Wire a Three-Phase Motor for Dual Voltages Rating ______

Comments: ______________________________

Job Sheet 5—Perform Maintenance on a Magnetic Motor Starter or Contactor Rating ______

Comments: ______________________________

Written Test Scores

Pretest ______ Posttest ______ Other ______

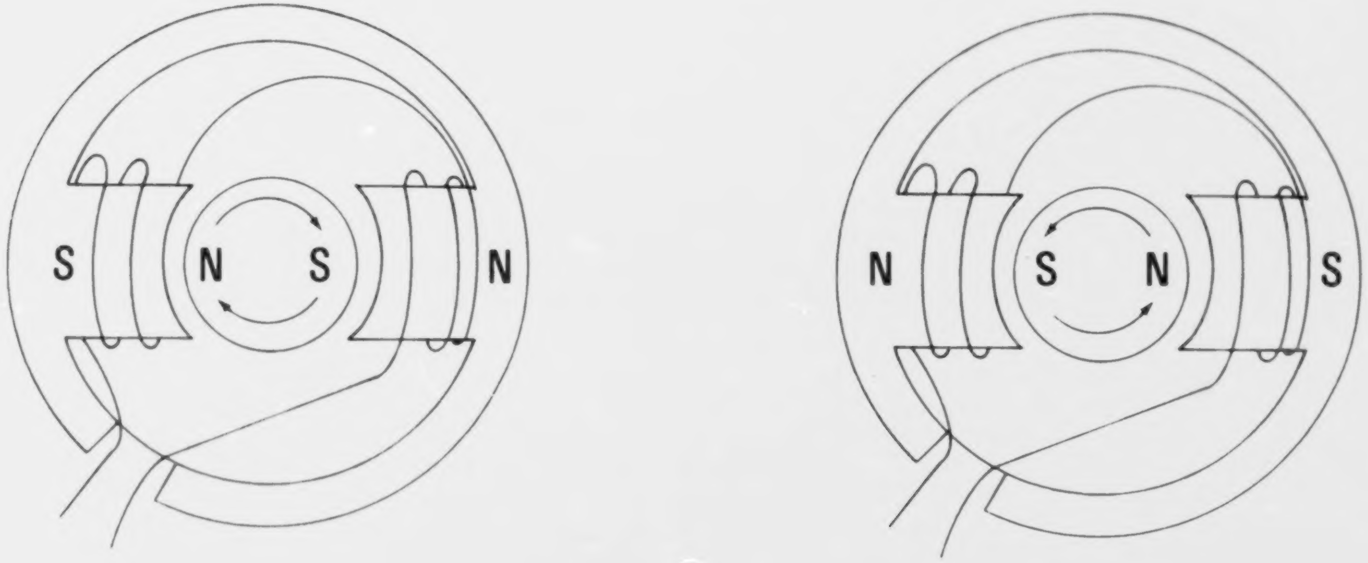
Other ______________________________

Teacher Signature ______________________ Date ____________

Student Signature ______________________ Date ____________

***Permission to duplicate this form is granted.**

Magnetic Poles in an Electric Motor

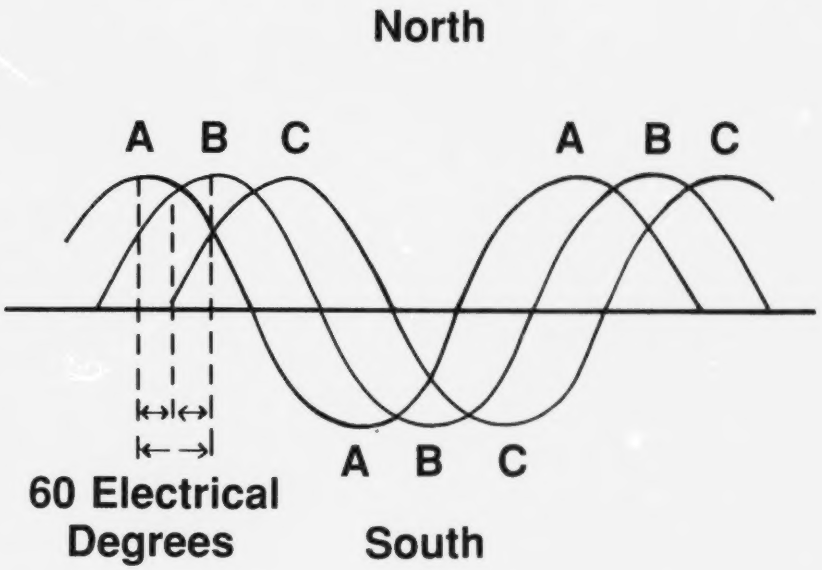


Reversing direction of current flow reverses magnetic polarity of poles.

Commercial and Industrial Wiring, Unit 7
Teacher Page 25

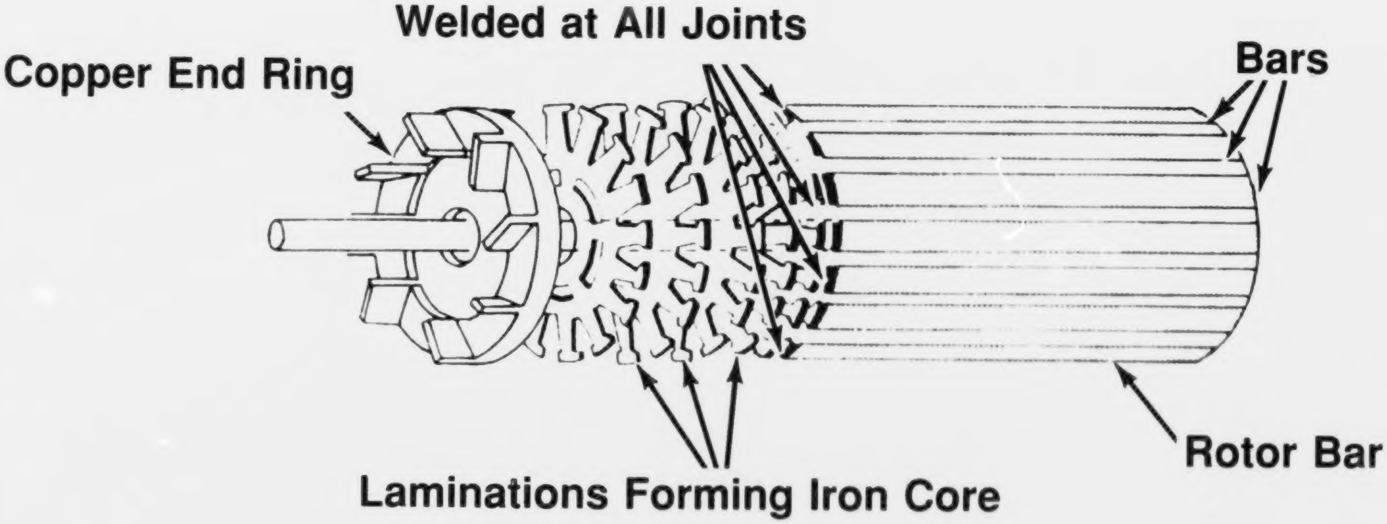
TM 1

Polyphase Magnetism


North
A
B
C
A
B
C
A
B
C
60 Electrical Degrees
South

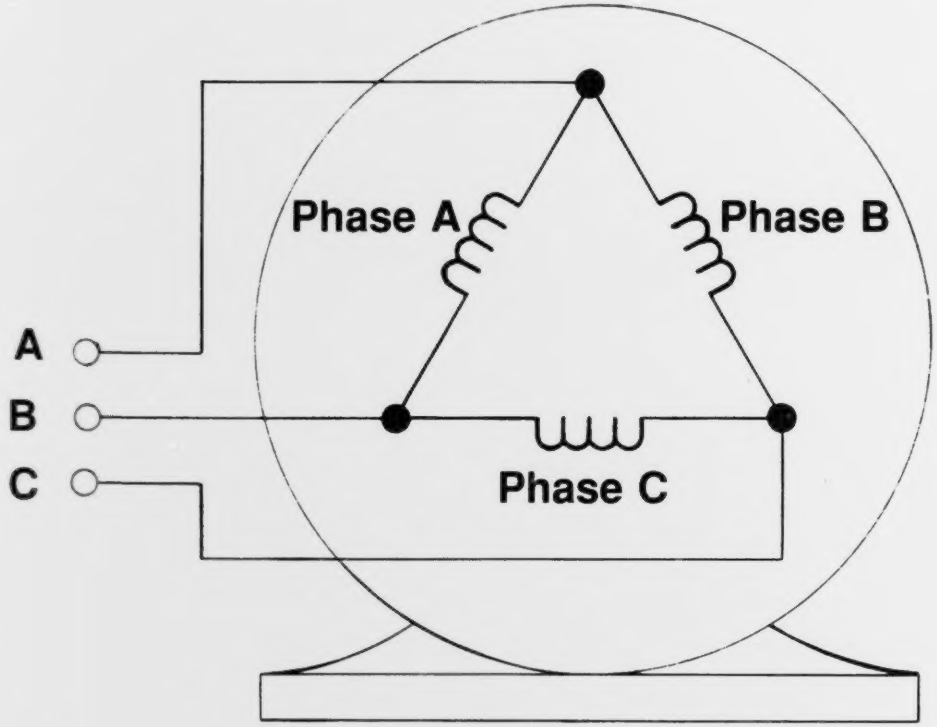
As the magnitude of each phase sine wave increases, so does the strength of the magnetic field it induces.

Squirrel-Cage Rotor


Welded at All Joints
Copper End Ring
Bars
Rotor Bar
Laminations Forming Iron Core

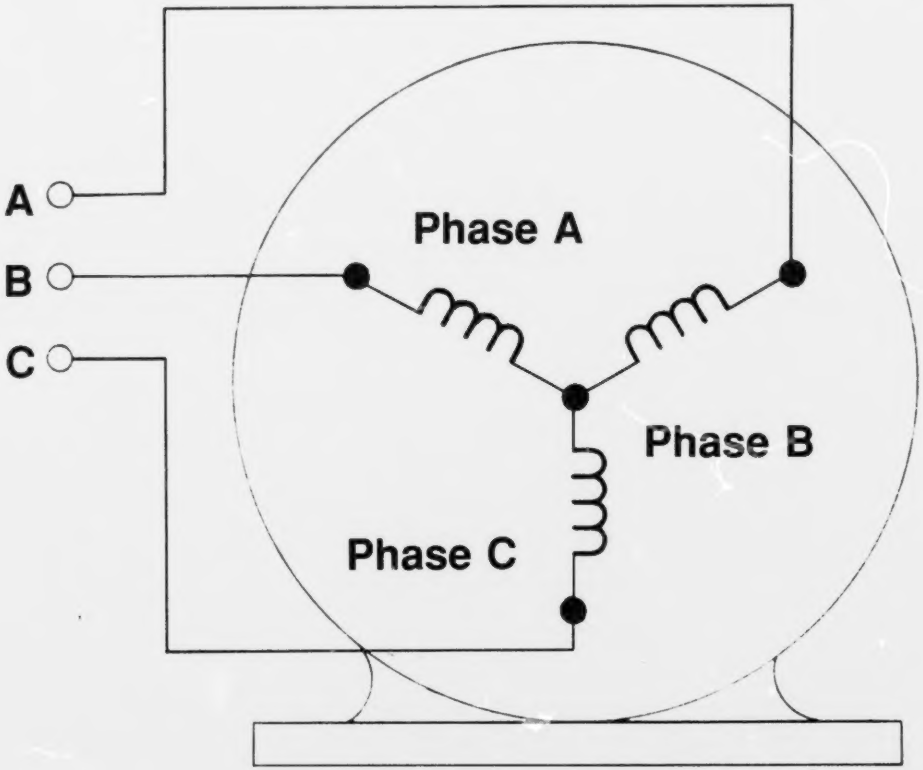
Commercial and Industrial Wiring, Unit 7
Teacher Page 29

Delta-Wound Motor

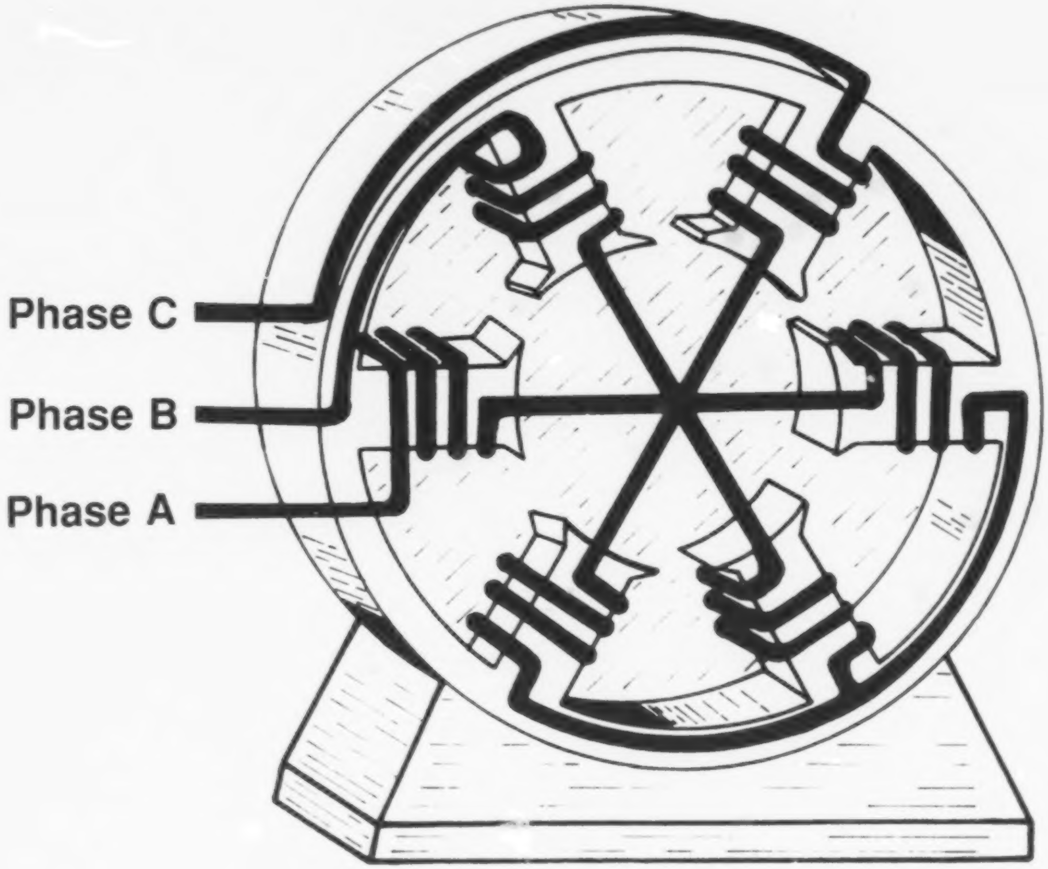

Phase A
Phase B
A
B
C
Phase C

Wye-Wound Motor

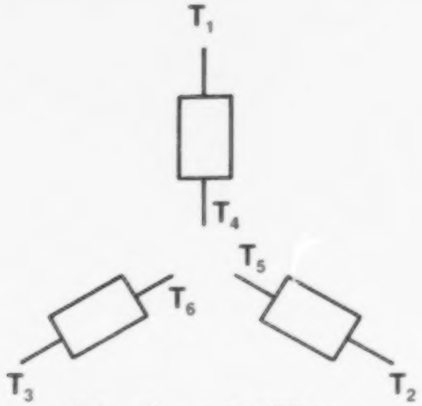
(Single Speed)


A
B
C
Phase A
Phase B
Phase C

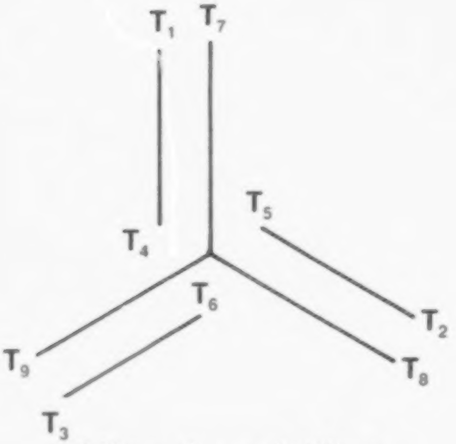
Three-Phase Motor Windings


Phase C
Phase B
Phase A

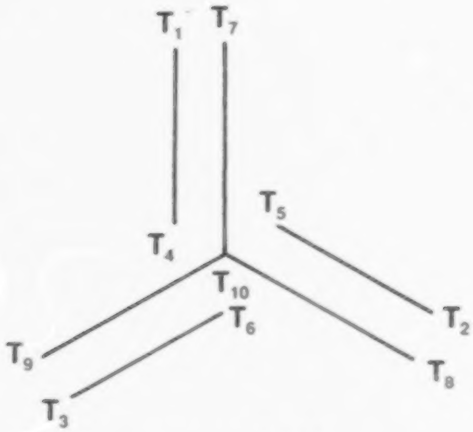
Dual Voltage Three-Phase Motor Showing Possible Six, Nine, and Ten Leads


T_1
T_4
T_5
T_6
T_3
T_2

Six-Lead Wye

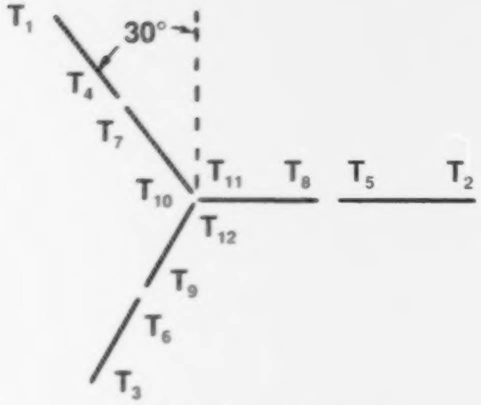

T_1
T_7
T_5
T_4
T_6
T_2
T_9
T_8
T_3

Nine-Lead Wye

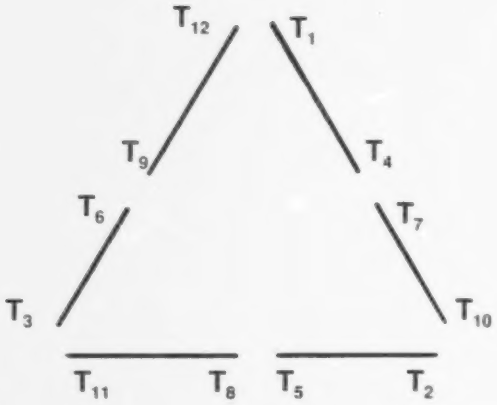

T_1
T_7
T_5
T_4
T_{10}
T_6
T_2
T_9
T_8
T_3

Ten-Lead Wye

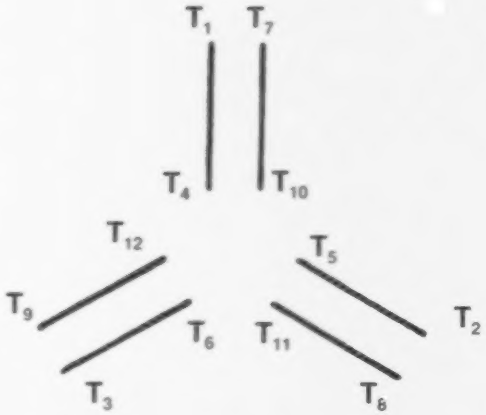
Dual Voltage Three-Phase Motor Showing Possible Twelve Leads


T_1
30°
T_4
T_7
T_{10}
T_{11}
T_8
T_5
T_2
T_{12}
T_9
T_6
T_3

Twelve-Lead Wye (High Voltage)


T_{12}
T_1
T_9
T_4
T_6
T_7
T_3
T_{10}
T_{11}
T_8
T_5
T_2

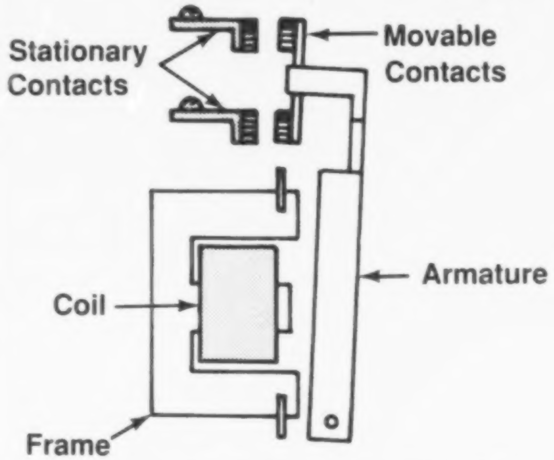
Twelve-Lead Delta (High Voltage)

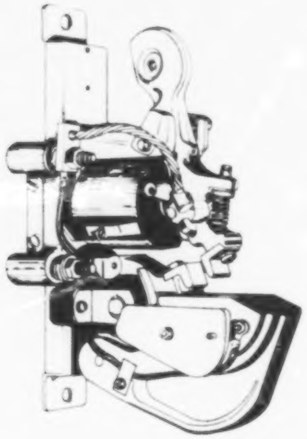

T_1
T_7
T_4
T_{10}
T_{12}
T_5
T_9
T_6
T_{11}
T_2
T_3
T_8

Twelve-Lead Wye (Low Voltage)

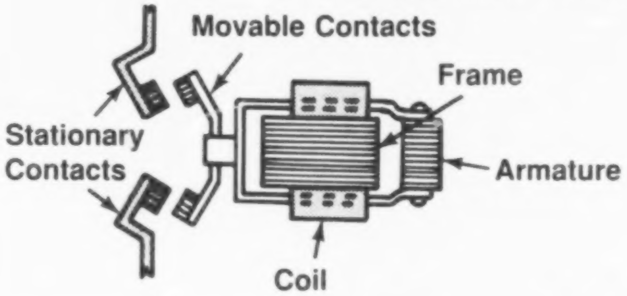
Types of Magnetic Contactor Assemblies

Clapper

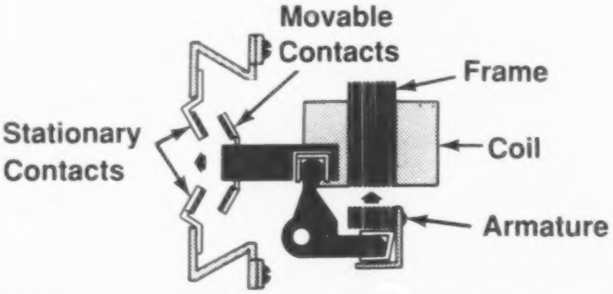

Stationary Contacts
Movable Contacts
Coil
Armature
Frame

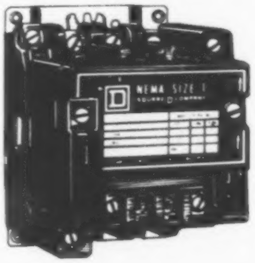


Horizontal Action


Movable Contacts
Frame
Stationary Contacts
Armature
Coil

Bell Crank


Movable Contacts
Frame
Stationary Contacts
Coil
Armature



Adapted with permission of Cutler-Hammer Products/Eaton Corp.; Allen-Bradley, a Rockwell International Company, Milwaukee, Wisconsin; and courtesy of Square D Company.

Motors and Controllers
Unit 7

Information Sheet

1. **Terms and definitions**

   a. **Arc chute** — Partition between contacts to reduce electrical arcing

   b. **Armature** — Portion of coil assembly moved by magnetism

   c. **Contactor** — Device used to make or break a motor's power circuit

   d. **Delta** — Three-phase circuit in which the windings are connected in series to form a closed loop

   e. **Dual voltage motor** — Motor capable of being wired to run at two different voltages

   f. **Power factor** — Ratio of active power to apparent power

   g. **Relay** — Operated by a change in one electrical circuit to control a device in the same circuit or another circuit; used in control circuits

   h. **Shading coil** — Single turn of conducting material mounted on the magnetic assembly face to produce out-of-phase magnetic force

   i. **Single phasing** — Loss of one phase of a three-phase system

   j. **Starter** — Device used to make and break electrical power circuit

   k. **Thermal overload (heater)** — Device used to sense current draw in a circuit and open a control circuit when its rating is exceeded

   l. **Torque** — Force that produces a rotating or twisting action

   Note: Amount of torque is expressed in foot-pounds.

   m. **Wye** — Three-phase circuit in which the windings are connected to form the shape of a "Y" (120 electrical degrees apart)

2. **Direct-current motor theory of operation (DC motors)**

   Note: Direct-current motors rotate through the interaction of two magnetic fields.

   a. A magnetic field is produced at the face of the stationary poles.

   b. A magnetic field is produced in the **armature** winding.

   c. The fields repel each other causing the **armature** to rotate.

Information Sheet

3. **Types of DC motors**

   a. Shunt motor

   Note: A shunt motor has the field connected in parallel with its armature.

   b. Series motor

   Note: A series motor has the fields connected in series with the armature.

   c. Compound motor

   Note: A compound motor has a combination of series and shunt windings. The series windings are connected in series with the armature and the shunt windings are connected in parallel.

4. **Single phase motor theory of operation**

   a. The motor operates on a single wave form from a two-wire A/C system.

   b. A/C single phase current produces a varying magnetic field.

   Note: The varying field, when applied directly to the field windings of most single phase motors cannot produce starting torque. Series motors contain an armature winding in series with the main winding and develop sufficient starting torque.

5. **Types of single phase motors**

   Note: Average starting torques of single-phase motors are expressed as percentages of the running torque of each motor.

   a. Shaded pole (100% starting torque)

   Note: Shaded pole motors are used in small sizes only for timers, small fans, light duty kitchen appliances, etc.

   b. Split phase (200% starting torque)

   c. Capacitor (300% starting torque)

   d. Induction repulsion (400% starting torque)

   e. Series (500% starting torque)

Information Sheet

6. **Three-phase motor theory of operation**

   Note: Three-phase motors are the workhorses of industry. They are rugged and reliable and the most dependable type of motor.

   a. Current in the stator produces a rotating magnetic field.

   b. Currents induced in the rotor create a magnetic field.

   c. The rotor turns, seeking an opposite pole.

7. **Types of three-phase motors**

   Note: An unloaded or lightly loaded three-phase motor will continue to run but will not start under single phase conditions.

   a. Squirrel cage induction

      Note: This is the most commonly used motor in industrial applications.

   b. Wound rotor

      Note: This is commonly called a slip-ring motor.

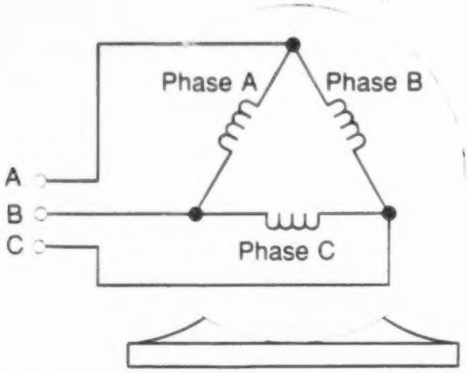
   c. Synchronous

      Note: Synchronous motors are frequently used for power-factor correction. When used for this purpose, they are known as synchronous condensers.

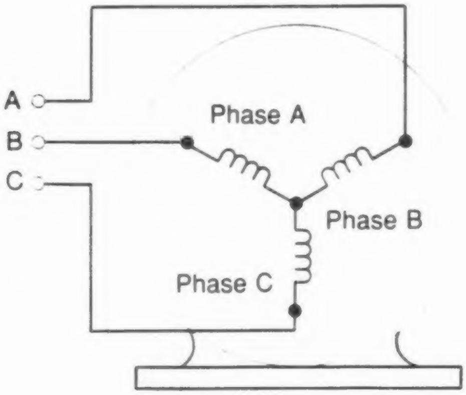
Information Sheet

8. **Reversing rotation of three-phase motors** — A three-phase motor is reversed by interchanging any two of the three supply lines anywhere between the motor and the source of supply.

Example: Delta-Wound Motor


Phase A
Phase B
A
B
C
Phase C

Example: Wye-Wound Motor (Single Speed)


A
B
C
Phase A
Phase B
Phase C

9. **Typical supply voltages for three-phase motors**

   a. 240-volt three-phase delta

   b. 480-volt three-phase delta

   c. 208-volt three-phase wye

   d. 480-volt three-phase wye

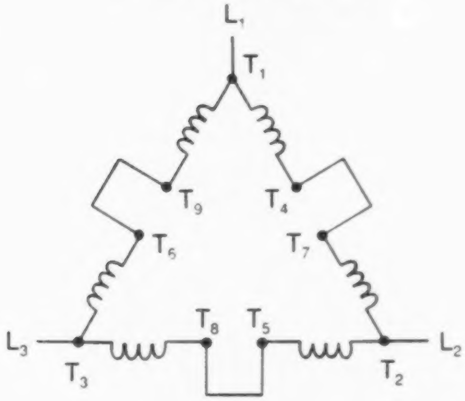
Information Sheet

10. Dual voltage schematics and terminal connections

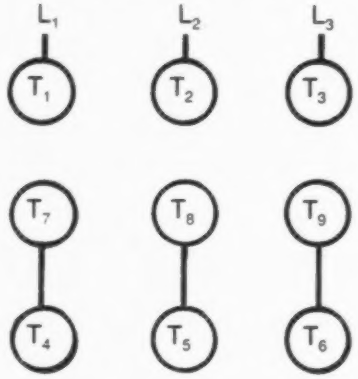
a. Delta-wound nine-lead high voltage motor

Note: On a typical 240/480-volt dual-voltage motor the 240-volt windings would wire in parallel and the 480-volt windings would wire in series, as shown.

Schematic Connection

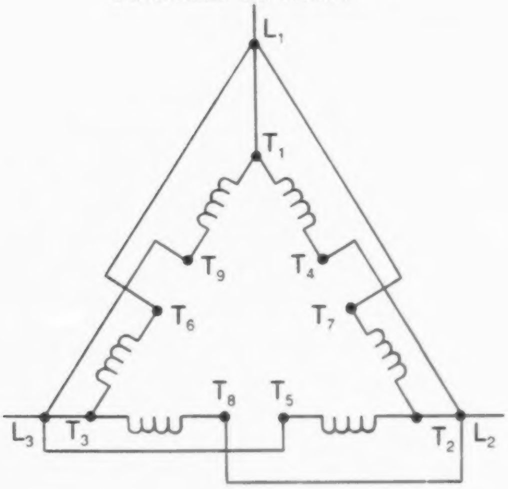

L_1
T_1
T_9
T_4
T_6
T_7
T_8
T_5
L_3
T_3
T_2
L_2

Terminal Connection

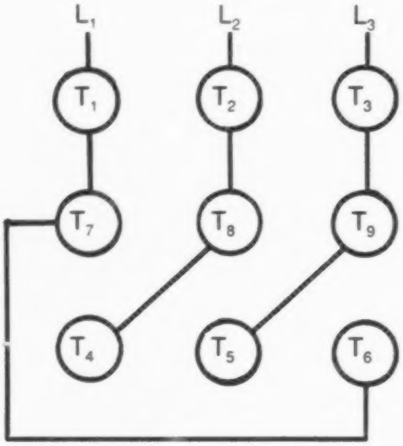

L_1
L_2
L_3
T_1
T_2
T_3
T_7
T_8
T_9
T_4
T_5
T_6

b. Delta-wound nine-lead low voltage motor

Schematic Connection


L_1
T_1
T_9
T_4
T_6
T_7
T_8
T_5
L_3
T_3
T_2
L_2

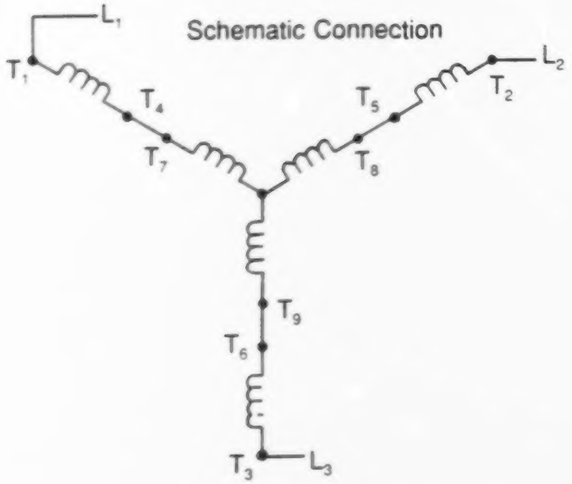
Terminal Connection


L_1
L_2
L_3
T_1
T_2
T_3
T_7
T_8
T_9
T_4
T_5
T_6

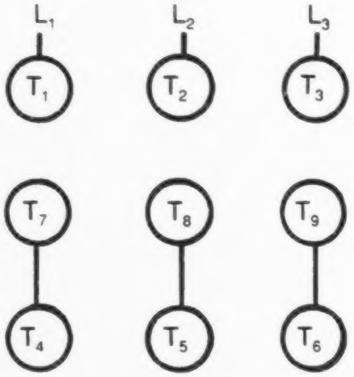
Information Sheet

c. Wye-wound nine-lead high voltage motor

Schematic Connection

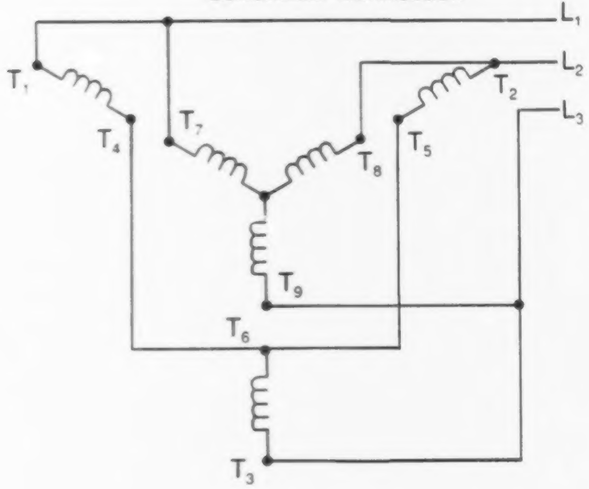

L₁
T₁
T₄
T₇
T₅
T₈
L₂
T₂
T₉
T₆
T₃
L₃

Terminal Connection

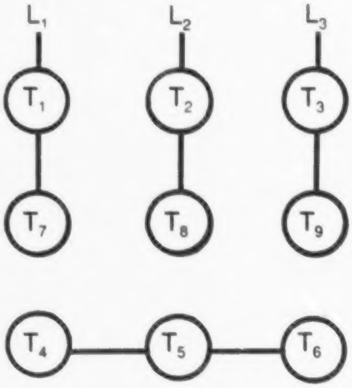

L₁
L₂
L₃
T₁
T₂
T₃
T₇
T₈
T₉
T₄
T₅
T₆

d. Wye-wound nine-lead low voltage motor

Schematic Connection


L₁
L₂
L₃
T₁
T₂
T₄
T₇
T₈
T₅
T₉
T₆
T₃

Terminal Connection


L₁
L₂
L₃
T₁
T₂
T₃
T₇
T₈
T₉
T₄
T₅
T₆

Information Sheet

11. Motor problems and their typical symptoms

a. Failure to start

- Blown fuse or open circuit breaker
- Low voltage or no voltage
- Open wiring circuit
- Incorrect power line connection
- Excessive load
- Excessive end play
- Seized or worn bearings
- Open overload

b. Excessive noise

- Unbalanced parts

  Examples: Bearings, pulley, rotor
- Bent shaft
- Loose parts
- Faulty alignment
- Worn bearings
- Dirt in air gap between rotor and stator
- Uneven air gap
- Shorted silicon-controlled rectifier (SCR) drive unit

c. Overheated bearings

- Lack of oil
- Dirty oil
- Oil not reaching shaft

Information Sheet

- Excessive grease or oil
- Excessive belt tension
- Rough bearing surface
- Bent shaft
- Misalignment of shaft and bearing
- Excessive end thrust
- Excessive side pull
- Belt slippage

d. Overheated motor

- Obstruction of ventilating system
- Overloading
- Open overload
- Rotor dragging on stator
- Incorrect voltage
- High ambient temperature
- Lack of oil

12. Remedies for motor problems

a. Failure to start

- Check supply voltage.

  Note: Supply voltage should be within 10 percent of motor nameplate voltage. If no voltage, reset breaker or check fuses.

- Check motor wiring with ohmmeter.
- Remove load from motor and try to start.
- Move motor shaft by hand to check for end play, side play, and bearing tightness.

Information Sheet

b. Excessive noise

- Replace out-of-balance pulley.
- Remove pulley and check straightness of shaft.
- Tighten motor accessories and mounting.
- Align drive pulley with driven pulley.
- Replace bearings.
- Clean motor.
- Check for out-of-round motor.

c. Overheated bearings

- Use recommended nondetergent motor bearing oil.
- Put clean oil in reservoir.

  Note: This will be possible only on large motors with bearing oil reservoirs.
- Clean excessive grease buildup from ball bearings.
- Adjust belt to proper tension.
- Move motor shaft by hand to check for end play, side play, and bearing tightness.
- Replace rough or worn bearings.
- Remove pulley and check for bent shaft.
- Align drive pulley with driven pulley.

d. Overheated motor

- Clean motor.
- Adjust belt tension.
- Check full load amperage.

Information Sheet

- Check for correct voltage.

  Note: A voltage check should be made at the motor terminals with the motor under load.

- Check for loose bearings.
- Check for tight bearings.
- Check pulley alignment.
- Remove pulley and check for bent shaft.

13. **Safety rules to observe when working around motors**

    a. Do not underestimate the danger of the circuit.

    b. Use caution around electric arcs.

    c. Never install equipment that will overload the circuit.

    d. Never bypass protective devices.

    e. Protect all wires from physical and thermal hazards.

    f. Tag and lock electrical disconnects when working on motors or motor circuits.

    g. Wear eye protection.

    h. Do not touch moving parts.

    i. Ground all electric motor frames.

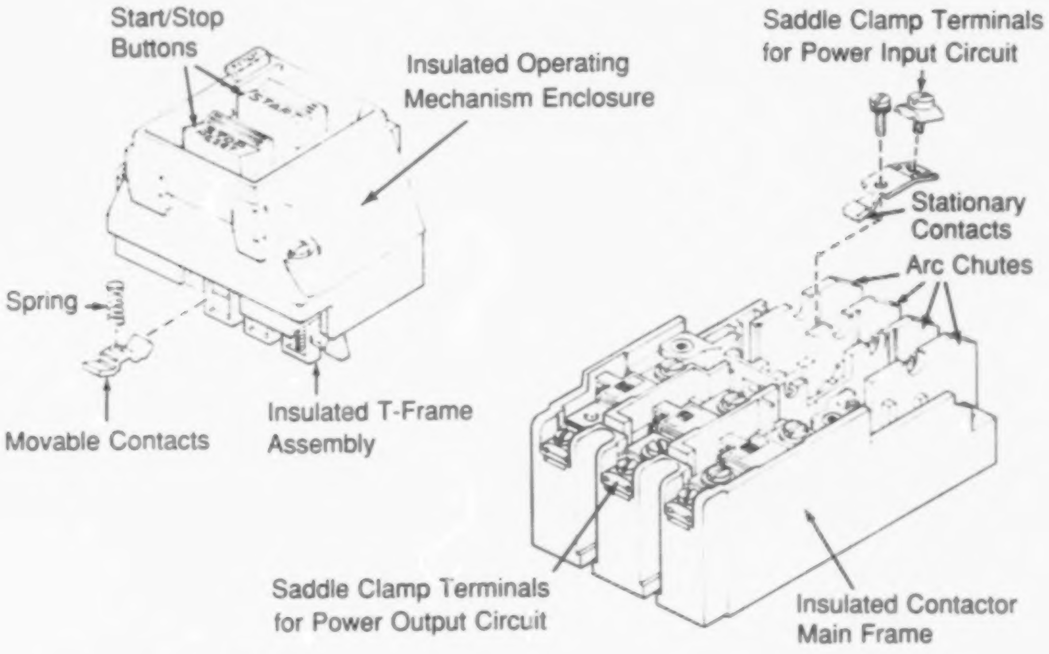
14. **Types of contactors**

    a. Manual

    b. Magnetic

Information Sheet

15. Parts of a manual contactor


Start/Stop Buttons
Insulated Operating Mechanism Enclosure
Saddle Clamp Terminals for Power Input Circuit
Stationary Contacts
Arc Chutes
Spring
Movable Contacts
Insulated T-Frame Assembly
Saddle Clamp Terminals for Power Output Circuit
Insulated Contactor Main Frame

Courtesy of Square D Company.

16. Electrical devices and circuits controlled by magnetic contactors

a. Lighting loads

b. Heaters

c. Transformers

d. Capacitors

e. Power circuits

17. Types of motor starters

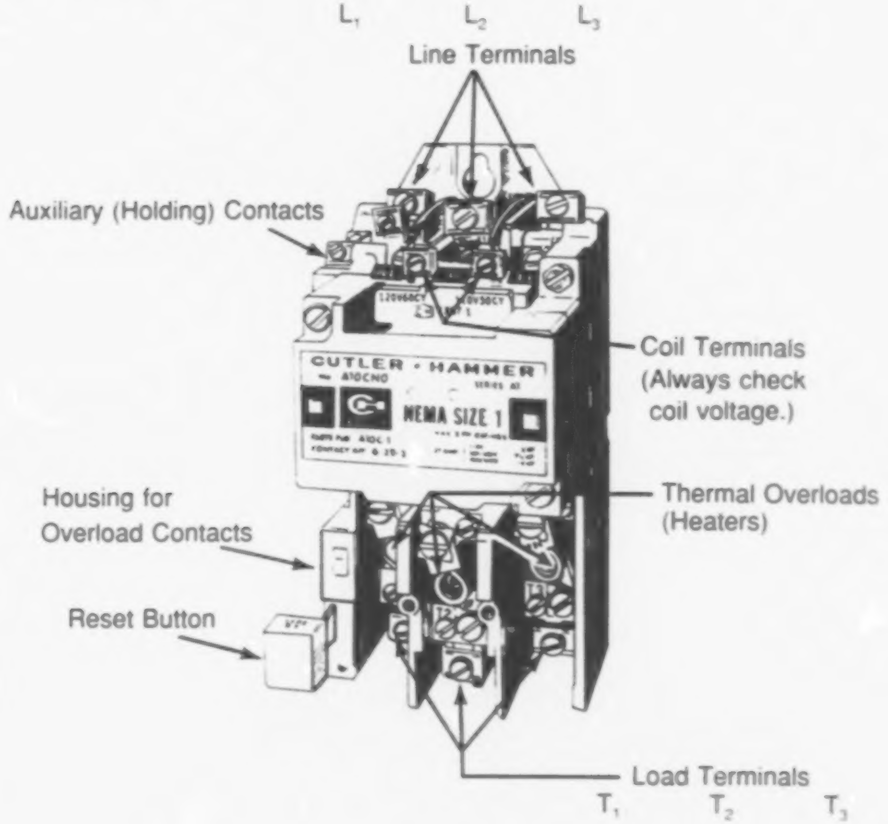
a. Manual

b. Magnetic

Information Sheet

18. **Types of magnetic motor starters**

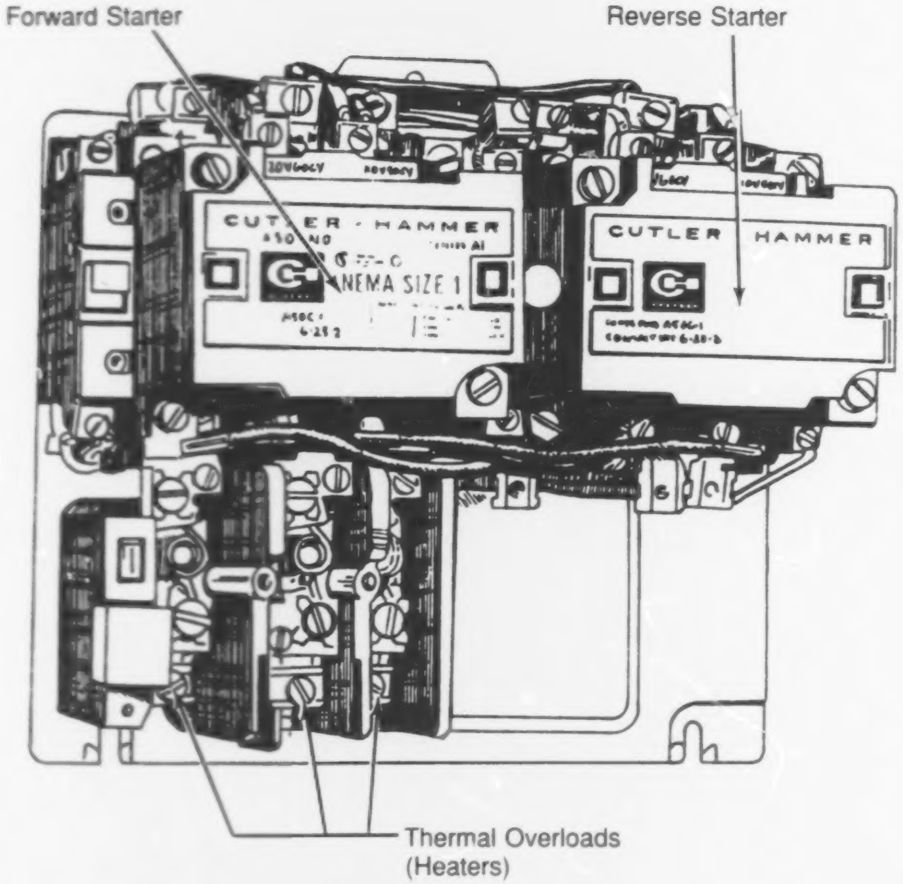
    a. Starting


L_1 L_2 L_3
Line Terminals
Auxiliary (Holding) Contacts
CUTLER · HAMMER
NEMA SIZE 1
Coil Terminals (Always check coil voltage.)
Thermal Overloads (Heaters)
Housing for Overload Contacts
Reset Button
Load Terminals
T_1 T_2 T_3

Adapted with permission of Cutler-Hammer Products/Eaton Corporation.

Information Sheet

b. Reversing

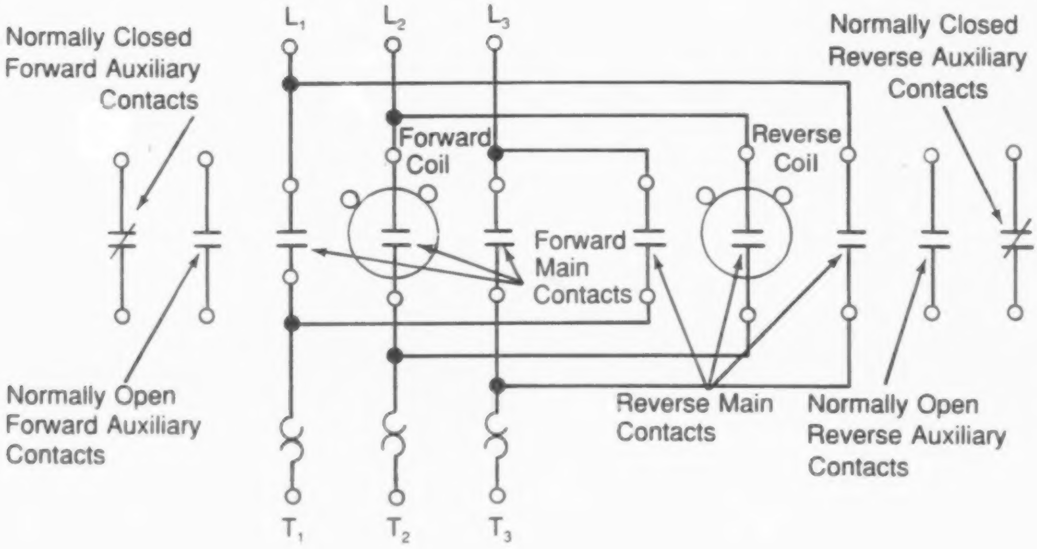

Forward Starter
Reverse Starter
CUTLER-HAMMER
NEMA SIZE 1
CUTLER HAMMER
Thermal Overloads
(Heaters)

Used with permission of Cutler-Hammer Products/Eaton Corporation.

Information Sheet

Note: Reversing any two phases will change rotation of the motor. In the example. L_1 and L_3 are reversed.

Example:


L₁
L₂
L₃
Normally Closed Forward Auxiliary Contacts
Normally Closed Reverse Auxiliary Contacts
Forward Coil
Reverse Coil
Forward Main Contacts
Normally Open Forward Auxiliary Contacts
Reverse Main Contacts
Normally Open Reverse Auxiliary Contacts
T₁
T₂
T₃

19. **Uses of magnetic motor starters**

    a. Starting motors

    b. Reversing motors

    c. Braking motors to stop

    d. Controlling speed of motors

Information Sheet

20. Comparison of parts in magnetic contactors and parts in magnetic motor starters

Note: Motor starters are contactors with overload protection for the motor.

Table 1

Parts	Contactors	Motor Starters
Line terminals	Yes	Yes
Power contacts	Yes	Yes
Load terminals	Yes	Yes
Holding contacts	Yes	Yes
Coil	Yes	Yes
Thermal overloads (heaters)	No	Yes
Reset button	No	Yes
Overload contact	No	Yes

21. Reasons a contactor cannot be used to control a motor

a. A contactor does not provide running overload protection for the motor.

b. A contactor is not designed for high inrush current for motor starting.

c. A contactor does not contain a set of overload contacts.

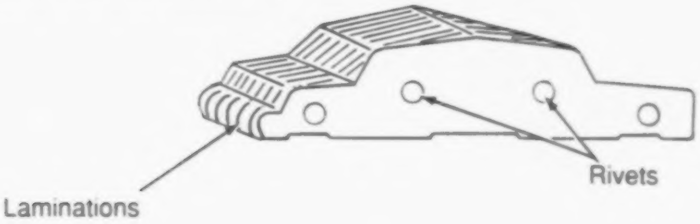
22. Purposes of a coil assembly

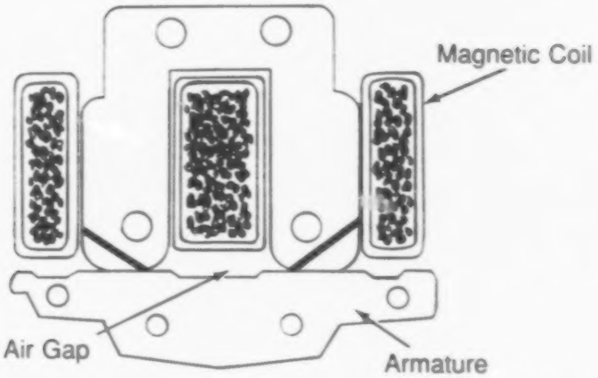
a. To change an electrical signal to a magnetic signal

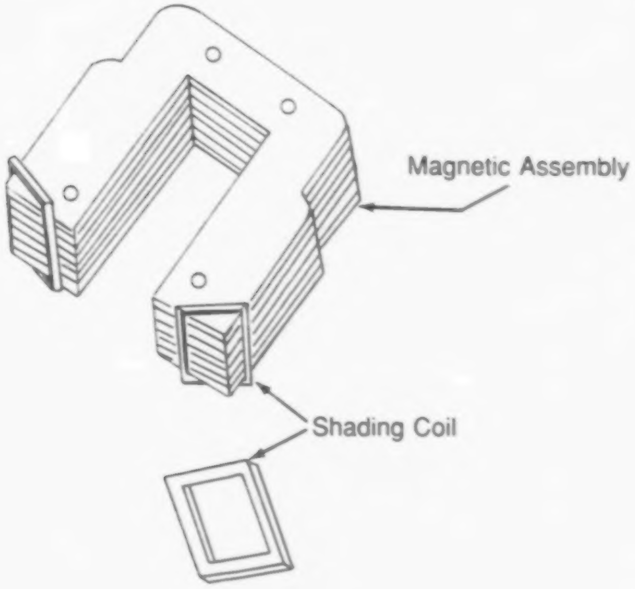
b. To activate the mechanical portion of the motor starter

Information Sheet

23. Parts of a coil assembly


Laminations
Rivets


Magnetic Coil
Air Gap
Armature


Magnetic Assembly
Shading Coil

Motors and Controllers
Unit 7

Assignment Sheet 1—Interpret Nameplate Information

Name ______________________________ Overall Rating __________

Evaluation Criteria	**Rating**
Correct information for motor selected	______
Answered all questions	______

Directions: The industrial electrician must be able to interpret motor nameplate information in order to be able to service and repair a motor. Select an electric motor as specified by your instructor. Use the information on the nameplate to answer the following questions. The above criteria will be used to evaluate your performance.

A. What is the horsepower of the motor? ______________________

B. Is this a single-phase or three-phase motor? ______________________

C. At how many revolutions per minute does the motor operate? ______________________

D. What is the recommended voltage to which this motor should be connected? ______

E. What type of overload protection does the motor have? ______________________

F. How long is the motor designed to operate? ______________________

G. Under what temperature will the motor operate? ______________________

H. What is the identification number? ______________________

I. At how many cycles per second does the motor operate? ______________________

J. What is the motor type? ______________________

K. What type of current does the motor use? ______________________

L. What is the service factor of the motor? ______________________

M. What type of mounting is used? ______________________

Motors and Controllers
Unit 7

Assignment Sheet 2—Describe Remedies for Common Motor Problems

Name ______________________ Overall Rating __________

Evaluation Criteria	**Rating**
Correct answers given	______
Adequate number of alternative possibilities listed	______

Directions: The industrial electrician must be able to determine causes and remedy common motor problems. In the following situations, the problems are stated. List possible solutions for each problem. The above criteria will be used to evaluate your performance.

A. Motor fails to start — ______________________

B. Motor is overheating — ______________________

Assignment Sheet 2

C. Motor is excessively noisy —

D. Motor bearings are overheating —

Motors and Controllers
Unit 7

Assignment Sheet 3—Use the *National Electrical Code* to Answer Questions About Motor Control Circuits

Name ______________________________ Overall Rating __________

Evaluation Criteria	Rating
Demonstrated proper use of the *NEC*	______
Gave correct answers	______

Directions: The industrial electrician must be able to interpret and apply the *National Electrical Code* by properly wiring all motor control circuits according to information found in Article 430. Use the *National Electrical Code* to answer the following questions. The above criteria will be used to evaluate your performance.

A. State the section of the *National Electrical Code* that deals with overcurrent protection.

____

B. List two exceptions for conductor protection in motor control circuits.

1. ____
2. ____

C. Is a transformer used to step down voltage for motor control circuits exempt from Article 430? ______________________________

D. Describe the *National Electrical Code* requirements for protecting control conductors.

____

E. State the time when motor control circuits must be disconnected.

____

F. Define a motor control circuit.

____

____

Assignment Sheet 3

G. State procedures for protecting conductors in control circuits.

H. Define "in sight" as it applies to motors and controllers.

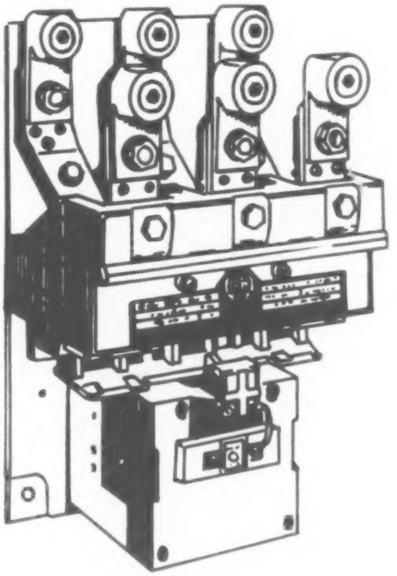
Motors and Controllers
Unit 7

Assignment Sheet 4—Distinguish Between Motor Starters and Contactors

Name ______________________________ Overall Rating __________

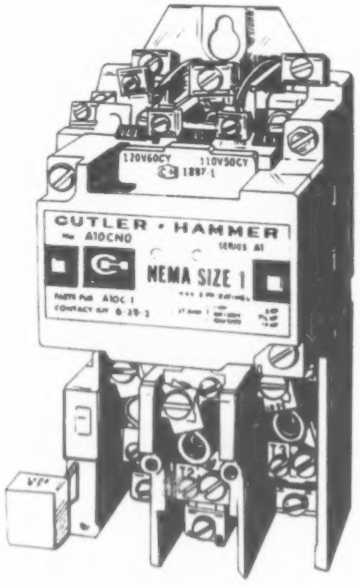
Evaluation Criteria	**Rating**
Illustrations correctly identified	______
Correct answers given to questions	______

Directions: When servicing existing equipment, an electrician must be able to identify at a glance a motor starter or a contactor. Contactors never have thermal overloads (heaters), reset buttons, or overload contacts. Look at the following pictures. Label each "contactor" or "motor starter," then answer the questions that follow. The above criteria will be used to evaluate your performance.



A. ______________________________

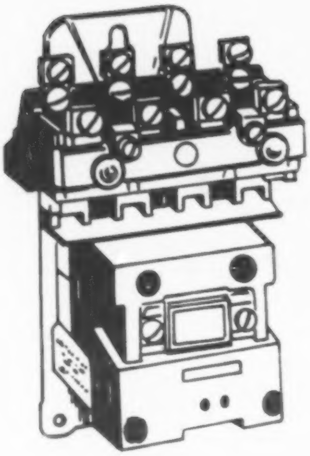
Adapted with permission of Allen-Bradley, a Rockwell International Company, Milwaukee, Wisconsin.

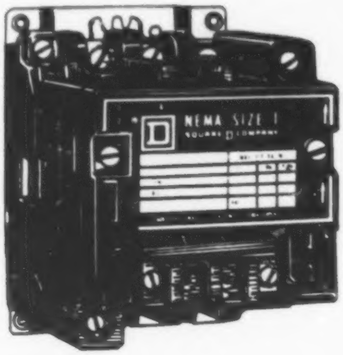


B. ______________________________

Adapted with permission of Cutler-Hammer Products/Eaton Corporation.

Assignment Sheet 4



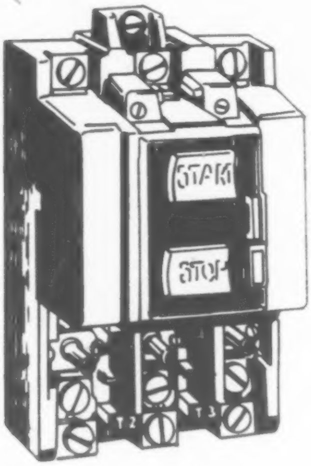

NEMA SIZE 1
SQUARE D COMPANY

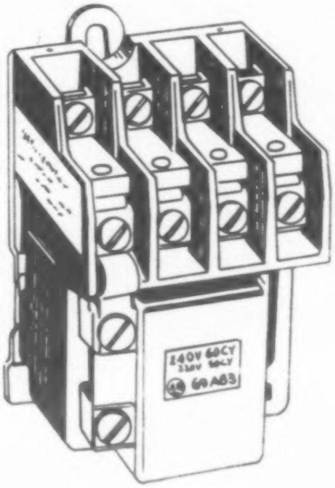
C. ______________________________

Adapted with permission of Allen-Bradley, a Rockwell International Company, Milwaukee, Wisconsin.

D. ______________________________

Courtesy of Square D Company.


START
STOP
T2
T3


440V 60CY
60A83

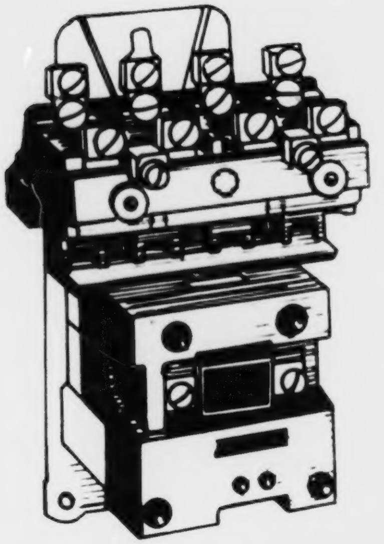
E. ______________________________

Adapted with permission of Cutler-Hammer Products/ Eaton Corporation.

F. ______________________________

Adapted with permission of Allen-Bradley, a Rockwell International Company, Milwaukee, Wisconsin.

Assignment Sheet 4



G. ______________________________

Adapted with permission of Allen-Bradley, a Rockwell International Company, Milwaukee, Wisconsin.

H. Which items did you recognize as being contactors. ______________________________

Explain why you selected these items as contactors.

____

____

____

I. Which items did you select as being motor starters? ______________________________

Explain why you selected these items as motor starters.

____

____

____

Motors and Controllers
Unit 7

Assignment Sheet 5—Answer Questions About Uses of Contactors and Motor Starters

Name ______________________________ Overall Rating __________

Evaluation Criteria	**Rating**
Correct answers given	______
Answered all questions	______

Directions: An industrial electrician must be able to select a motor starter or contactor according to its correct use. Contactors are used to make and break an electrical power circuit. Motor starters are used to make and break a motor's power circuit. Complete each of the following questions about motor starters and contactors and their uses. The above criteria will be used to evaluate your performance.

A. Which of the following lists contains contactor parts and which contains motor starter parts? Write "contactor" or "motor starter" in the blank above the correct column.

1. ______________	2. ______________
Line terminals	Line terminals
Load terminals	Load terminals
Power contacts	Coil
Coil	Holding contacts
Holding contacts	Power contacts
Overload contact	
Reset button	
Thermal overloads (heaters)	

B. Name five uses of magnetic contactors.

1. ____
2. ____
3. ____
4. ____
5. ____

Assignment Sheet 5

C. List four uses of magnetic motor starters.

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________

D. State three reasons why a contactor cannot be used to control a motor.

1. ______________________________
____
2. ______________________________
____
3. ______________________________
____

Motors and Controllers
Unit 7

Job Sheet 1—Disassemble, Inspect, and Clean a Motor

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Disassembled and cleaned motor correctly	______
Reassembled motor correctly	______
Motor runs	______
Demonstrated good workmanship	______

Instructions: When you are ready to perform this task, ask your instructor to observe th procedure and rate your performance using the above criteria.

A. Tools and materials

Split-phase motor
Screwdriver set
Combination wrench set
Center punch
Ball peen hammer
Soft-faced hammer
Small socket wrench set
Motor cleaning fluid
Clean shop towel
Compressed air
Eye protection
Lead marking material
Polishing cloth
Gear puller
Machine oil

B. Procedure

☐ 1. Observe safety rules throughout this procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Put on eye protection.

☐ 4. Check to be sure that electrical power is disconnected and locked open.

☐ 5. Remove motor from equipment, if necessary, and mark leads.

Job Sheet 1

☐ 6. Clean outer surface of motor.

☐ 7. Disconnect wires at motor terminals.

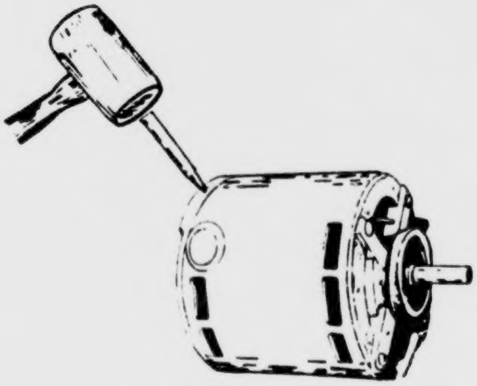
Note: Label wire positions by number or color on motor terminals, or draw a diagram.

☐ 8. Remove motor pulley.

☐ 9. Mark end bells to keep them in their proper places.

- Using center punch, place one mark on pulley end bell and two marks on opposite end bell.
- Mark housing in the same way.

Figure 1

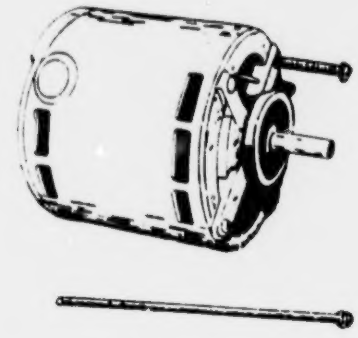


☐ 10. Check motor for end play.

Job Sheet 1

☐ 11. Remove bolts holding end bells.

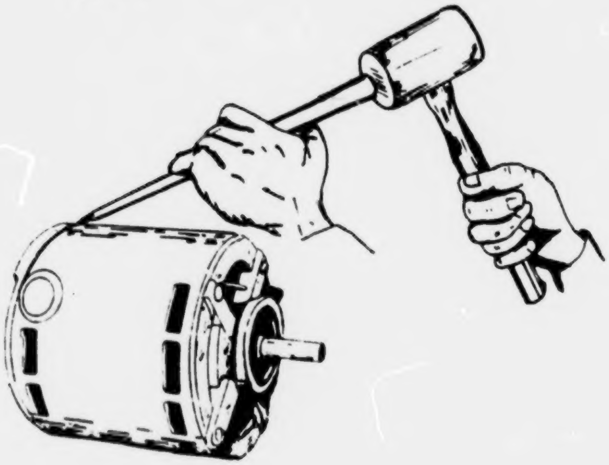
Figure 2



☐ 12. Polish shaft ends for easy removal.

☐ 13. Use soft-faced hammer and punch to tap end bells loose.

Figure 3



☐ 14. Remove end bell that does not contain starting switch.

☐ 15. Remove rotor.

Note: Observe position and number of thrust washers as you remove the rotor.

Job Sheet 1

☐ 16. Remove end bell containing starting switch.

Caution: Do not attempt to remove the stator.

☐ 17. Clean motor with compressed air.

☐ 18. Check centrifugal mechanism and starting switch.

☐ 19. Clean outside of motor with special cleaning fluid.

☐ 20. Check stator coils, insulation, and coil supports.

☐ 21. Clean bearings, and make sure that wicking is in place and oiled.

Caution: Do not clean ball bearings with compressed air.

☐ 22. Reinstall end bell containing starting switch.

☐ 23. Insert rotor, making sure that thrust washers are in place.

Note: Place a drop of oil on the bearing part of the shaft.

☐ 24. Reinstall second end bell.

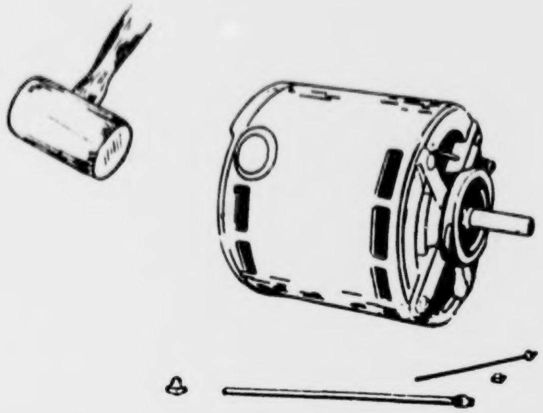
☐ 25. Visually inspect rotor and stator alignment.

☐ 26. Check position of end bells to center punch marks.

Job Sheet 1

☐ 27. Use soft-faced hammer to tap end bells into place.

Figure 4



☐ 28. Insert end-bell bolts; tighten.

☐ 29. Turn shaft by hand, and check for end play.

Note: If shaft is tight, end bells may not be in proper alignment, or the wicking may be between the bearing and the shaft.

☐ 30. Connect temporary leads; test motor.

☐ 31. Return tools and materials to proper storage.

☐ 32. Clean the work area.

Evaluator's comments: ____

____

____

Motors and Controllers
Unit 7

Job Sheet 2—Identify Run, Common, and Start Terminals on Hermetically Sealed Motors

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation Criteria	Rating
Practiced safety rules throughout procedure	______
Motor 1 terminals correctly identified	______
Motor 2 terminals correctly identified	______
Motor 3 terminals correctly identified	______
Demonstrated good workmanship	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Ohmmeter with leads and test clips
Three hermetically sealed compressor units
Paper to sketch terminals and record ohm readings
Pen or pencil

B. Procedure

☐ 1. Observe safety rules throughout this procedure.

☐ 2. Check out proper tools and materials.

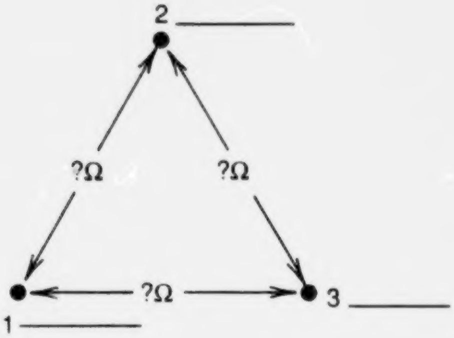
☐ 3. Clean terminals to ensure good connections.

Note: The terminals on most units are *not* identified.

Job Sheet 2

☐ 4. Draw sketch of compressor unit electrical terminals as shown in Figure 1.

Figure 1



☐ 5. Test and record ohms between terminals 1 and 2.

1 to 2 = ________________ ohms

☐ 6. Test and record ohms between terminals 2 and 3.

2 to 3 = ________________ ohms

☐ 7. Test and record ohms between terminals 1 and 3.

1 to 3 = ________________ ohms

☐ 8. Analyze readings and label sketch as in Figures 2 through 4.

Figure 2

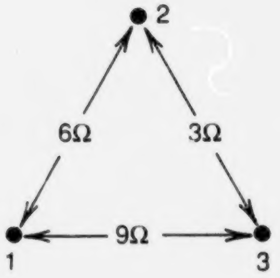


Figure 3

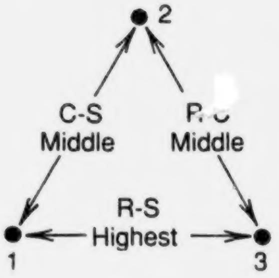
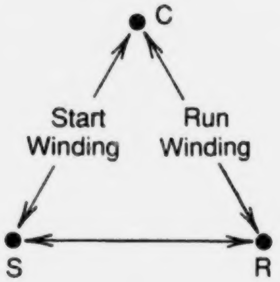

2
C-S
Middle
R-C
Middle
R-S
Highest
1
3

Figure 4


C
Start
Winding
Run
Winding
S
R

Job Sheet 2

Note: The run winding has larger wire, so it has the lowest resistance (R is common to highest and lowest readings). The start winding has smaller wire and more terminals, so it has a higher reading (S is common to highest and middle readings). The combined resistance of run and start windings is measured between R and S, so it gives the highest reading (C is common to middle and lowest readings).

☐ 9. Repeat steps 3 through 6 on at least two more compressor units.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's comments: ____

____

____

Motors and Controllers
Unit 7

Job Sheet 3—Test Capacitors with an Ohmmeter

Name ______________________________ Attempt Number __________

Date ______________________________ Overall Rating __________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Capacitor 1 accurately tested	______
Capacitor 2 accurately tested	______
Capacitor 3 accurately tested	______
Capacitor 4 accurately tested	______
Capacitor 5 accurately tested	______
Capacitor 6 accurately tested	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

1,000-ohm ohmmeter with leads
Six start or run capacitors with clean terminals
Bleeder resistor with attached leads, approximately 75 ohms

Note: The TIF-CT-660 capacitor tester has proven to be a good, inexpensive tool for these tests; however, ohmmeters may also be used.

Eye protection

B. Procedure

☐ 1. Observe safety rules throughout this procedure.

☐ 2. Check out proper tools and materials.

Job Sheet 3

☐ 3. Put on eye protection.

☐ 4. Apply bleeder resistor across capacitor terminals long enough to be sure that capacitor is discharged.

☐ 5. Set ohmmeter on R × 1,000 range.

☐ 6. Set ohmmeter leads and zero instrument.

☐ 7. Test for ground on run capacitors.

- Connect one ohmmeter lead to case.
- Touch other lead to capacitor terminal.

Note: If indicator moves toward zero, capacitor is probably bad and should be discarded. No movement of indicator indicates that unit is not grounded.

☐ 8. Test for open and charging ability.

- Discharge capacitor completely.
- Connect one lead to one capacitor terminal.

Note: Make a good connection.

- While watching ohmmeter, firmly contact other capacitor terminal with second lead.

Note: If the capacitor is good, the ohmmeter indicator will make a sudden move toward zero ohms, then stop and move less rapidly to the high resistance end of scale as the capacitor takes a charge from the voltage applied by the ohmmeter.

- Discharge capacitor and repeat test several times.

Note: If capacitor is open, the ohmmeter indicator will not move. If capacitor is shorted, the instrument will indicate zero or low resistance. If this occurs, discard the unit.

☐ 9. Repeat test procedure on each capacitor.

Note: Destroy bad units to prevent their reinstallation.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's comments: ______________________________

____

____

Motors and Controllers
Unit 7

Job Sheet 4—Wire a Three-Phase Motor for Dual Voltages

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation Criteria	Rating
Practiced safety rules throughout procedure	______
Made proper low-voltage connection	______
Made proper high-voltage connection	______
Reversed motor's rotation correctly	______
Demonstrated good workmanship	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Dual-voltage motor
Pouch tools
Wire nuts
Wire markers

B. Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Open motor lead connection box.

☐ 4. Separate leads.

☐ 5. Check motor name plate for low-voltage connections.

☐ 6. Hook up leads as shown on motor plate.

Job Sheet 4

☐ 7. Label leads that would go to L1, L2, and L3.

Note: Tell instructor the voltage you wired the motor for; have instructor inspect your work.

☐ 8. Disconnect all leads.

☐ 9. Check motor name plate for high-voltage connections.

☐ 10. Hook up leads as shown on motor name plate.

☐ 11. Mark leads that would go to L1, L2, and L3.

Note: Tell the instructor what voltage you set the motor up for; have instructor inspect your work.

☐ 12. Reverse the motor's rotation.

☐ 13. Return tools and materials to proper storage.

☐ 14. Clean the work area.

Evaluator's comments: ______________________________

____

____

Motors and Controllers
Unit 7

Job Sheet 5—Perform Maintenance on a Magnetic Motor Starter or Contactor

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
Practiced safety rules throughout procedure	______
Contacts operable	______
Armature clean	______
Unit operates	______
Demonstrated good workmanship	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

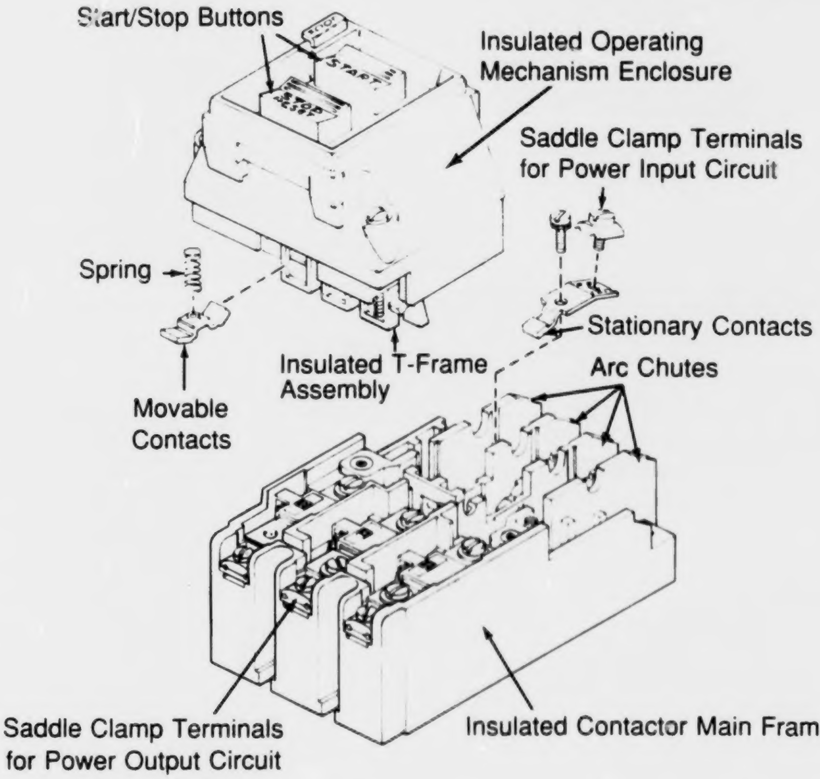
Contactor or motor starter
Screwdriver
Needle-nosed pliers
New magnetic coil
Wire brush

Job Sheet 5

B. Procedure

Note: Figure 1 illustrates a manual contactor; however, contacts are the same on manual and magnetic contactors and motor starters.

Figure 1


Start/Stop Buttons
STOP
START
Insulated Operating Mechanism Enclosure
Saddle Clamp Terminals for Power Input Circuit
Spring
Stationary Contacts
Arc Chutes
Insulated T-Frame Assembly
Movable Contacts
Saddle Clamp Terminals for Power Output Circuit
Insulated Contactor Main Frame

Courtesy of Square D Company.

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Remove screws holding insulated operating mechanism enclosure to insulated contactor main frame.

☐ 4. Gently pull operating mechanism enclosure from main frame.

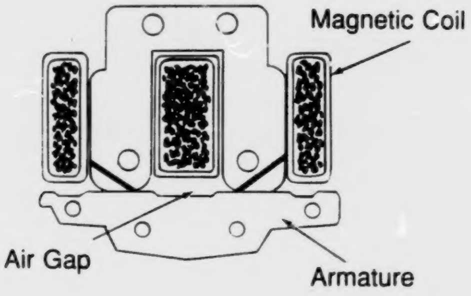
Job Sheet 5

☐ 5. Locate moveable contacts; remove them from holder.

Note: Take care not to allow the small spring on top of the contact to jump out and become lost.

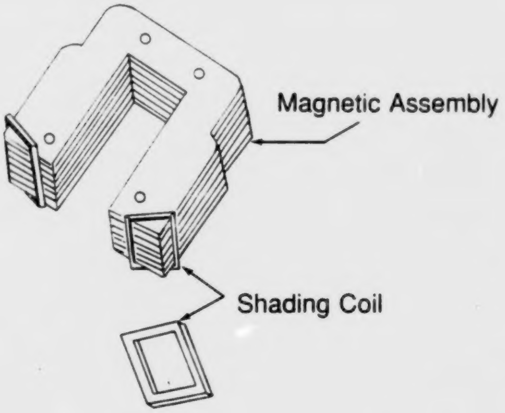
☐ 6. Replace movable contacts and springs.

Figure 2


Magnetic Coil
Air Gap
Armature

☐ 7. Disassemble armature and coil assembly.

Figure 3


Magnetic Assembly
Shading Coil

☐ 8. Clean armature with wire brush.

☐ 9. Check shading coil to see that it is secure.

Job Sheet 5

☐ 10. Reassemble coil assembly.

☐ 11. Replace coil assembly in contactor or motor starter.

☐ 12. Replace coil cover.

☐ 13. Tighten coil cover screws.

☐ 14. Hook coil wires to coil terminals.

☐ 15. Return tools and materials to proper storage.

☐ 16. Clean the work area.

Evaluator's comments: ____

____

____

Electrical Diagrams and Symbols
Unit 8

Objective Sheet

Unit Objective

After completing this unit, the student should be able to draw and interpret electrical control diagrams. The student should demonstrate these competencies by completing the assignment sheets, and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to electrical diagrams with their correct definitions.
2. Complete characteristics of wiring diagrams.
3. Select true statements concerning characteristics of ladder diagrams.
4. State the characteristics of one-line diagrams.
5. Identify wiring and ladder diagram symbols.
6. Arrange in order major steps in constructing a ladder diagram.
7. Construct a basic ladder diagram. (Assignment Sheet 1)
8. Identify electrical symbols in a wiring diagram. (Assignment Sheet 2)

Electrical Diagrams and Symbols
Unit 8

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan for students with special needs.
4. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.
5. Develop teaching plan. Adjust for different learning styles.
6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.
8. Discuss unit and specific objectives.
9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
10. Discuss the assignment sheets. Review criteria for evaluation of these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.
12. Make copies of the written test. Add or modify test items as needed.
13. Give written test.
14. Record assignment sheet ratings and written test scores on the Unit Evaluation Form. Add any additional assignments or supplemental activities that should be part of the unit evaluation.
15. Reteach and retest as required.

Suggested Activities

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Provide students with examples of wiring and ladder diagrams.
2. Have students evaluate sequence of operation of various ladder diagrams. Skill area: **problem solving**.

Resources Used in Developing This Unit

1. Kaltwasser, Stan and Gary Flowers. *Commercial and Industrial Wiring*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1988.
2. Rockis, Gary and Glen Mazur. *Electrical Motor Controls*. 2nd Ed. Alsip, IL: American Technical Publishers, 1987.
3. Teague, Cash and Garner Pewewardy. *Industrial Electricity: In-Plant Distribution*. Stillwater, OK: Oklahoma Curriculum and Instructional Materials Center, 1984.

Suggested Supplemental Resources

1. Croft, Terrell and Wilford I. Summers. *American Electrician's Handbook*, 11th Ed. New York: McGraw-Hill Book Company, 1987.
2. Earley, Mark W., John M. Caloggero and Richard H. Murray. *NEC Handbook 1993*. Quincy, MA: National Fire Protection Association, 1992.
3. *National Electrical Code 1993*. Quincy, MA: National Fire Protection Association, 1992.
4. O'Riley, Ronald P. *Illustrated Changes in the 1993 National Electrical Code*. Albany, NY: Delmar Publishers, Inc., 1993.

Suggested Activities

Instructions for Evaluating Student Performance

Assignment Sheets—Be sure the student understands the criteria on which the evaluation is based. Assign a point value to each criterion and convert the total points to a percentage for grading.

Job Sheets—Be sure the student understands the criteria on which the evaluation is based. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher edition or student manual. Then observe the student performing the procedure. Rate both process and product.

> Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.
>
> Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. Complete the rating by assigning a point value to each criterion and by converting the point total to a percentage for grading. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) which best fits your program needs.

Option A

4 - Skilled—Can perform job with no additional training.
3 - Moderately skilled—Has performed job during training program; limited additional training may be required.
2 - Limited skill—Has performed job during training program; additional training is required to develop skill.
1 - Unskilled—Is familiar with process, but is unable to perform job.

Option B

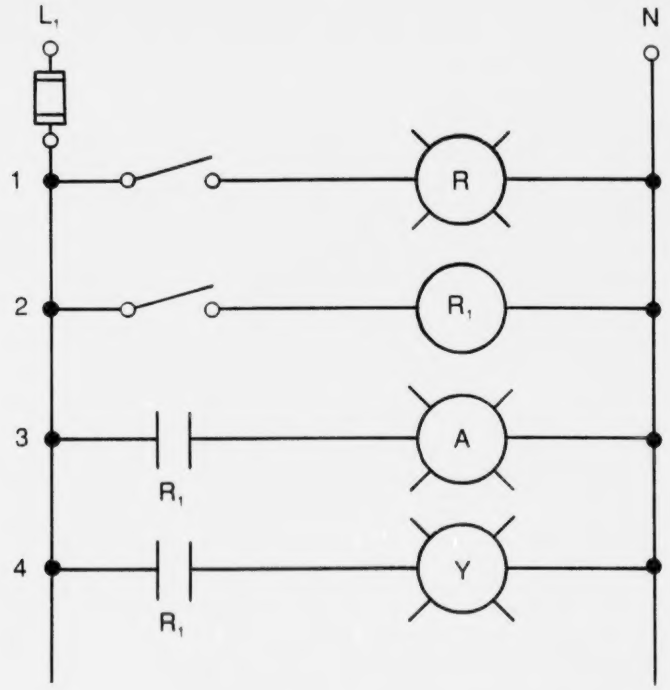
Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

Electrical Diagrams and Symbols
Unit 8

Answers to Assignment Sheets

Assignment Sheet 1



Assignment Sheet 2

A. Normally open push button (start)
B. Normally closed push button (stop)
C. Thermal overload relay
D. Auxiliary contact
E. Line and control wiring terminal
F. Main contact
G. T_2 motor lead terminal
H. Three-phase motor
I. Overload device switch

Electrical Diagrams and Symbols
Unit 8

Answers to Written Test

1.

a.	18	f.	15	k.	10	p.	3
b.	17	g.	13	l.	5	q.	1
c.	16	h.	6	m.	4	r.	2
d.	9	i.	14	n.	19	s.	8
e.	7	j.	12	o.	11		

2. a. Approximate
   b. Guide
   c. Symbols
   d. Power, control
   e. Trace

3. a, b, e

4. a. They show the location of transformers.
   b. They show the location of overcurrent devices.
   c. They indicate overcurrent device sizes.
   d. They indicate sizes of loads.
   e. They indicate characteristics of loads.

5. a. Limit switch (normally open)
   b. Standard resistor
   c. Foot switches
   d. Pilot lights
   e. Pressure and vacuum switches
   f. Time delay relay coil
   g. Momentary contact
   h. Maintained contacts
   i. Liquid level switch
   j. Thermal overload relay
   k. Flow switch
   l. Two-wire pilot device
   m. Temperature-actuated switch
   n. Plugging switch

6. a. 2
   b. 4
   c. 1
   d. 3
   e. 5

Electrical Diagrams and Symbols
Unit 8

Written Test

Name ______________________________________ Score ________________

1. Match the terms on the right with their correct definitions. Definitions are continued on the next page.

______a. Pilot device that delays closing or opening of a circuit for a specific time; may be motor driven, solenoid-actuated, or electric

______b. Control device with electric contactor and overload protection; designed to protect motor from voltage inrush during starting

______c. Manually operated multiposition switch

______d. Contactor operated electromechanically

______e. Momentarily operating; moving driven machine a small distance

______f. Device that controls electrical apparatus from some distance

______g. Switch, manually operable plunger, button, or actuating device

______h. Function of magnetic control that connects equipment directly to supply line on starting

______i. Electromechanical device operated by a coil; uses contacts to make or break circuits

______j. Device for protecting motor from overload current or voltage

______k. Starter designed to start motor at a reduced speed and build to full speed in preset steps

1. Across-the-line
2. Automatic starting
3. Auxiliary contact
4. Bimetal
5. Contactor
6. Full voltage control
7. Jogging
8. Ladder diagram
9. Magnetic contactor
10. Multispeed starter
11. One-line diagram
12. Overload relay
13. Push button
14. Relay
15. Remote control
16. Selector switch
17. Starter
18. Timer
19. Wiring diagram

Written Test

______l. Device without overload protection; repeatedly establishes and interrupts an electric power circuit

______m. Two different metals bonded to provide fast heat transfer to trip contacts by mechanical deflection

______n. Consists of symbols and lines that indicate all connections and placement of all component parts in a device or circuit, including the power circuit wiring

______o. Schematic consisting of single-phase and three-phase power lines; indicates power distribution and fuse and interrupter coordination

______p. Contact provided in addition to the main circuit contacts but operated with the main contacts

______q. Method of starting an electric motor by connecting it directly to supply line

______r. Pertaining to self-acting starter completely controlled by pilot switches or some other sensing device

______s. Schematic consisting of symbols and lines that indicate power source and how current flows through various parts of control circuit

2. Complete the following characteristics of wiring diagrams.

   a. They show components in their ____________ locations.

   b. They provide a ____________ for field wiring.

   c. They use standard electrical ____________.

   d. They show ____________ and ____________ lines together.

   e. They make circuits difficult to ____________

Written Test

3. Select true statements concerning characteristics of ladder diagrams by placing an "X" in the blank preceding each true statement.

______a. They resemble a ladder.

______b. They depict individual circuits as ladder rungs.

______c. They use mechanical symbols.

______d. They show power and control voltages together.

______e. They simplify circuit troubleshooting.

4. State the characteristics of one-line diagrams.

a. ______________________________

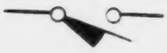
b. ______________________________

c. ______________________________

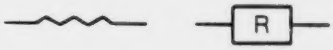
d. ______________________________

e. ______________________________

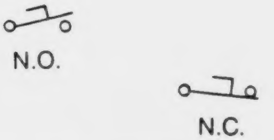
5. Identify the wiring and ladder diagram symbols shown below.



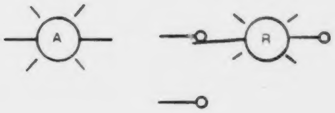
a. ____________________



b. ____________________

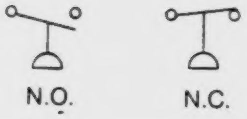


c. ____________________

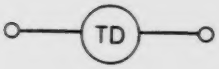


d. ____________________

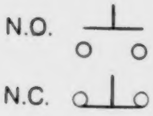
Written Test



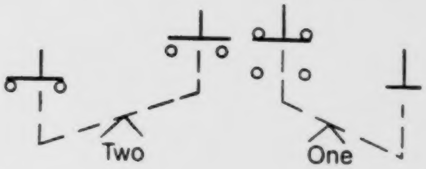
e. ____________________



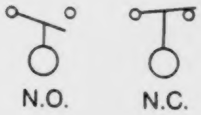
f. ____________________



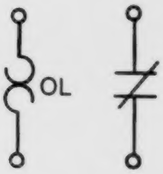
g. ____________________



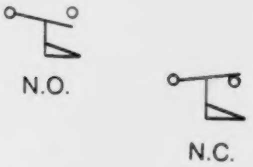
h. ____________________



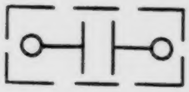
i. ____________________



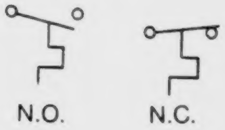
j. ____________________



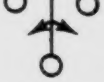
k. ____________________



l. ____________________



m. ____________________



n. ____________________

Written Test

6. Arrange in order the major steps in constructing a ladder diagram. Number the blanks in the appropriate sequence.

______a. Identify and label loads.

______b. Connect circuit wires, keeping ladder rungs equidistant for ease of reading.

______c. Establish and label power lines.

______d. Identify and label control devices and contacts for each circuit (rung).

______e. Number rungs, and cross reference.

*Permission to duplicate this test is granted.**

Electrical Diagrams and Symbols
Unit 8

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Assignment Sheet 1—Construct a Basic Ladder Diagram Rating ______

Comments: ____

____

Assignment Sheet 2—Identify Electrical Symbols in a Wiring Diagram Rating ______

Comments: ____

____

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ____

____

Teacher Signature ______________________________ Date __________

Student Signature ______________________________ Date __________

***Permission to duplicate this form is granted.**

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Electrical Diagrams and Symbols
Unit 8

Information Sheet

1. **Terms and definitions**

   a. **Across-the-line** — Method of starting an electric motor by connecting it directly to supply line

   b. **Automatic starting** — Pertaining to self-acting starter completely controlled by pilot switches or some other sensing device

   c. **Auxiliary contact** — Contact provided in addition to the main circuit contacts but operated with the main contacts

   Note: Auxiliary contacts are mechanically operated by the coil of the starter or contactor.

   d. **Bimetal** — Two different metals bonded to provide fast heat transfer to trip contacts by mechanical deflection

   Note: Bimetals are frequently used in thermal overload relays.

   e. **Contactor** — Device without overload protection; repeatedly establishes and interrupts an electric power circuit

   f. **Full voltage control** — Function of magnetic control that connects equipment directly to supply line on starting

   g. **Jogging (inching)** — Momentarily operating; moving driven machine a small distance

   h. **Ladder diagram (line diagram)** — Schematic consisting of symbols and lines that indicate power source and how current flows through various parts of a control circuit

   Note: Ladder diagrams depict control logic.

   i. **Magnetic contactor** — Contactor operated electromechanically

   j. **Multispeed starter** — Starter designed to start motor at a reduced speed and build to full speed in preset steps

   k. **One-line diagram** — Schematic consisting of single-phase and three-phase power lines; indicates power distribution and fuse and interrupter coordination

Information Sheet

l. **Overload relay** — Device for protecting motor from overload current or voltage

Note: An overload relay does not necessarily protect against short circuit, but does cause and maintain interruption from power supply until reset.

m. **Push button** — Switch, manually operable plunger, button, or actuating device

n. **Relay** — Electromechanical device operated by a coil; uses contacts to make or break circuits

o. **Remote control** — Device that controls electrical apparatus from some distance

p. **Selector switch** — Manually operated multiposition switch

Note: The selector switch is also called a *multiple-contact switch*.

q. **Starter** — Control device with electric contactor and overload protection; designed to protect motor from voltage inrush during starting

r. **Timer** — Pilot device that delays closing or opening of a circuit for a specific time; may be motor driven, solenoid-actuated, or electric

s. **Wiring diagram** — Consists of symbols and lines that indicate all connections and placement of all component parts in a device or circuit, including the power circuit wiring

Information Sheet

2. Characteristics of wiring diagrams

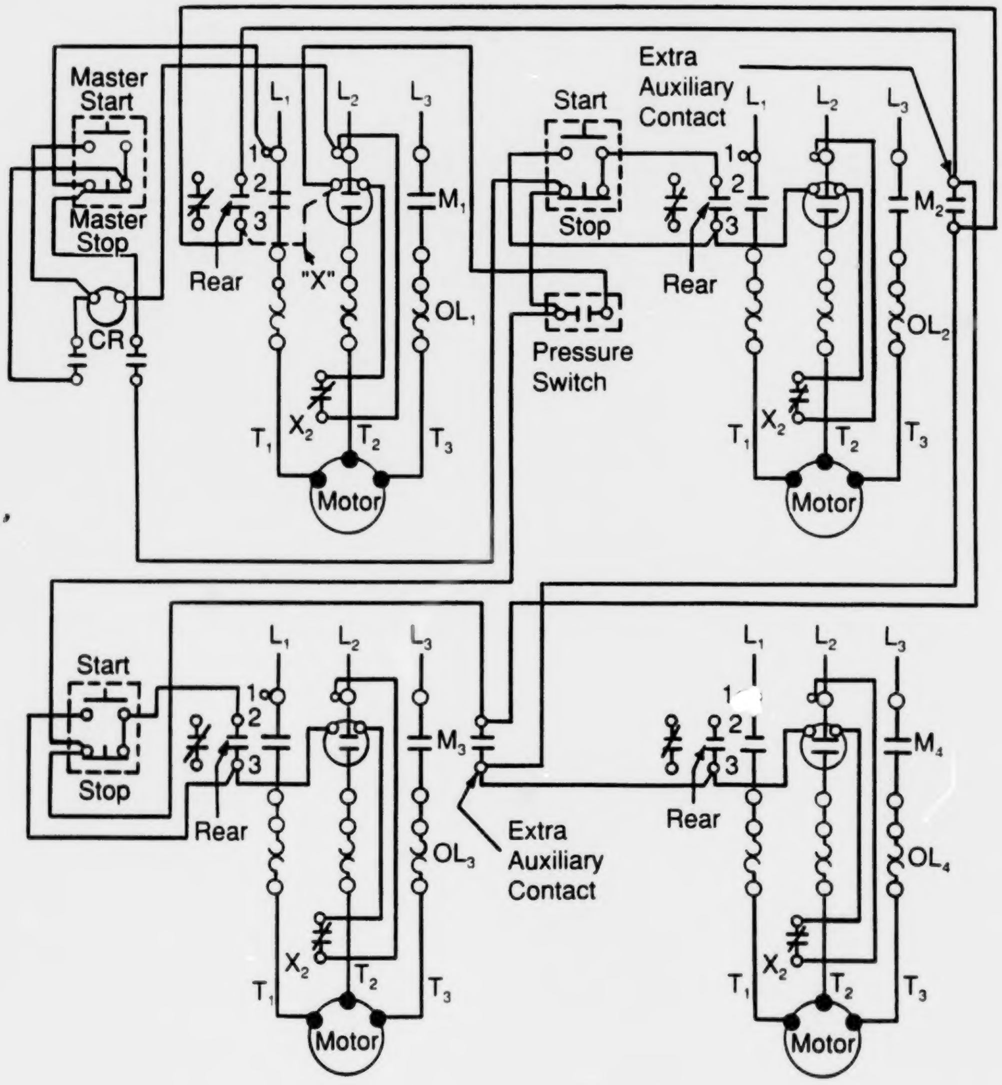
a. They show components in their approximate locations.

b. They provide a guide for field wiring.

c. They use standard electrical symbols.

d. They show power and control lines together.

e. They make circuits difficult to trace.


Master Start
Master Stop
CR
L₁
L₂
L₃
1
2
3
Rear
"X"
M₁
OL₁
X₂
T₁
T₂
T₃
Motor
Start
Stop
Extra Auxiliary Contact
Pressure Switch
M₂
OL₂
M₃
OL₃
M₄
OL₄

3. Characteristics of ladder diagrams

Note: The electrical industry is rapidly changing over to ladder diagrams; however, it is important that the electrical technician is able to read and interpret all types of diagrams.

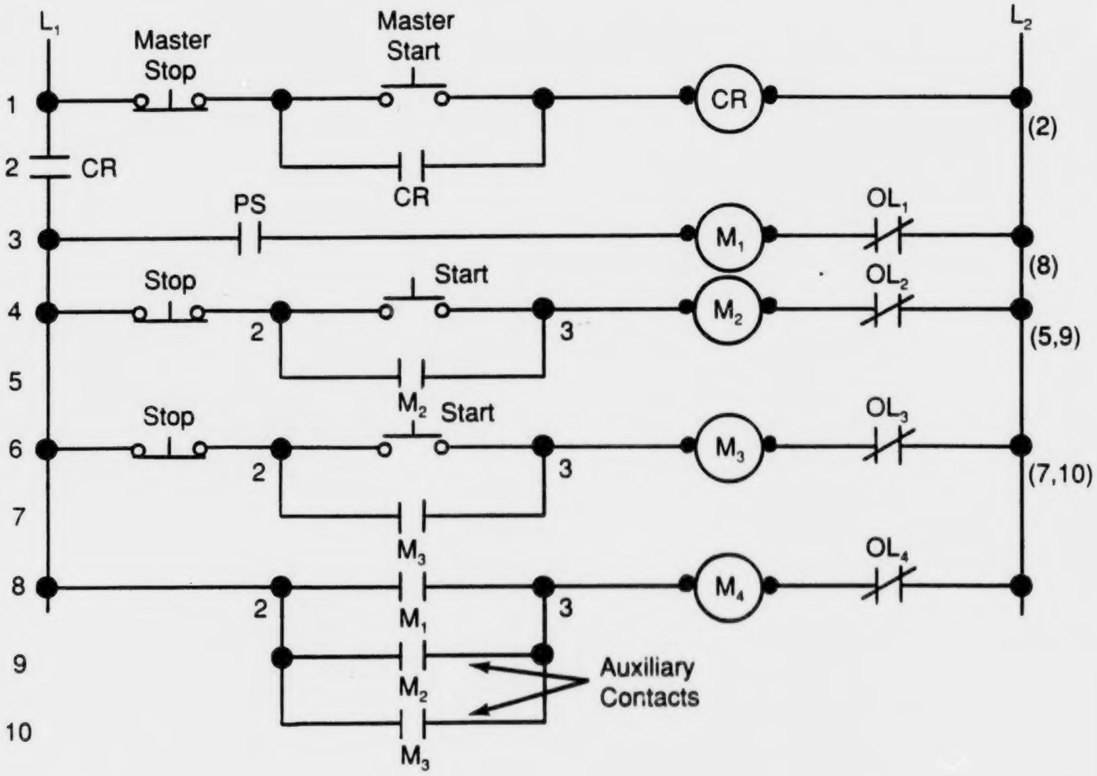
a. They resemble a ladder.

b. They depict individual circuits as ladder rungs.

c. They use standard electrical symbols.

d. They show separate power and control lines.

e. They simplify circuit troubleshooting.


L1
L2
Master Stop
Master Start
CR
CR
CR
(2)
PS
M1
OL1
(8)
Stop
Start
M2
OL2
(5,9)
Stop
M2
Start
M3
OL3
(7,10)
M3
M1
M4
OL4
M2
M3
2
3
Auxiliary Contacts
1
2
3
4
5
6
7
8
9
10

Information Sheet

4. Characteristics of one-line diagrams

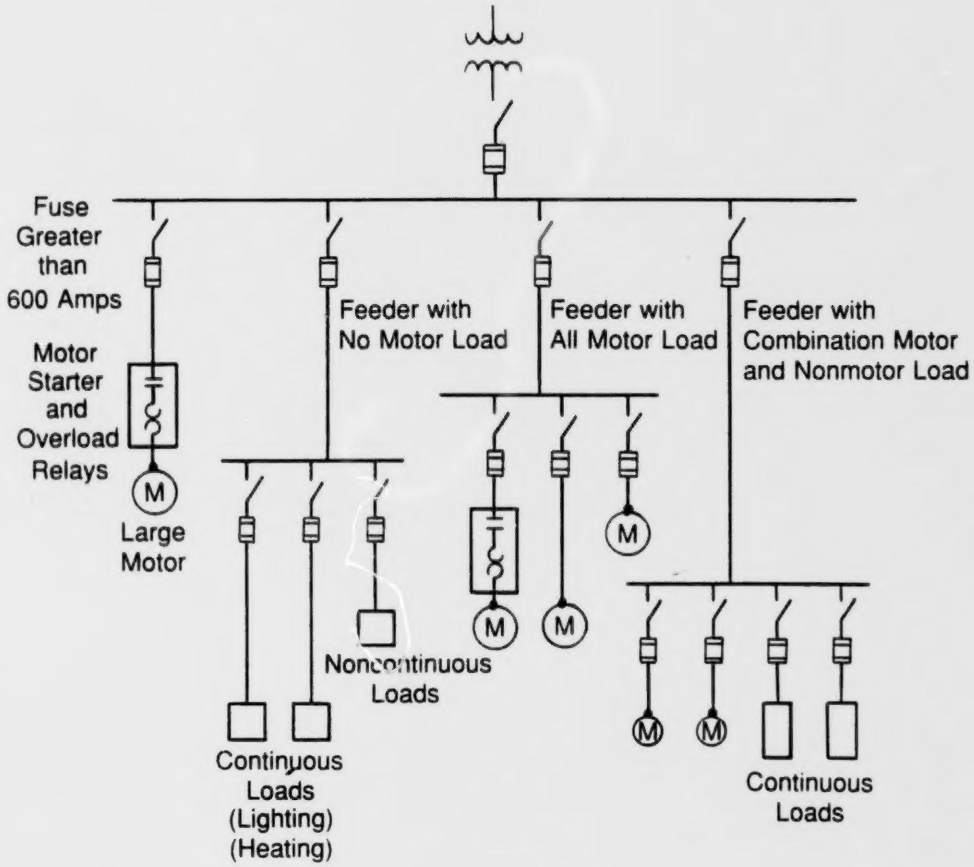
a. They show the location of transformers.

b. They show the location of overcurrent devices.

c. They indicate overcurrent device sizes.

d. They indicate sizes of loads.

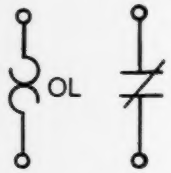
e. They indicate characteristics of loads.


Fuse Greater than 600 Amps
Motor Starter and Overload Relays
M
Large Motor
Feeder with No Motor Load
Feeder with All Motor Load
Feeder with Combination Motor and Nonmotor Load
M
M
M
Noncontinuous Loads
Continuous Loads (Lighting) (Heating)
M
M
Continuous Loads

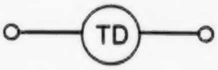
Information Sheet

5. Wiring and ladder diagram symbols

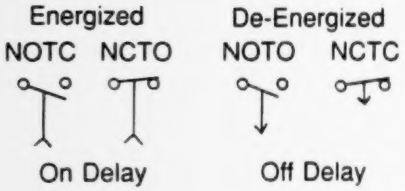
a. Thermal overload relay



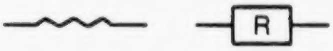
b. Time delay relay coil



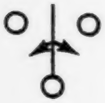
c. Timed contacts


Energized
De-Energized
NOTC
NCTO
NOTO
NCTC
On Delay
Off Delay

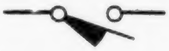
d. Standard resistor



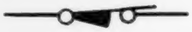
e. Plugging switch



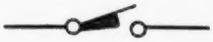
f. Limit switch (normally open)



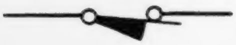
g. Limit switch (normally closed)



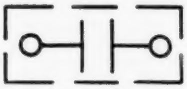
h. Limit switch (held open)



i. Limit switch (held closed)

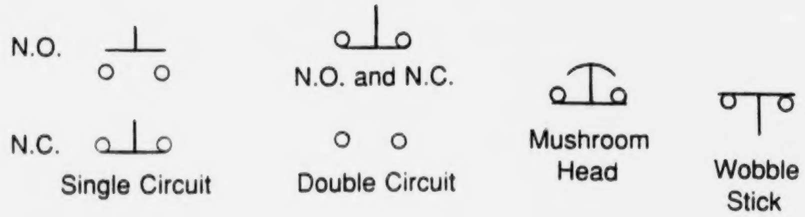


j. Two-wire pilot device

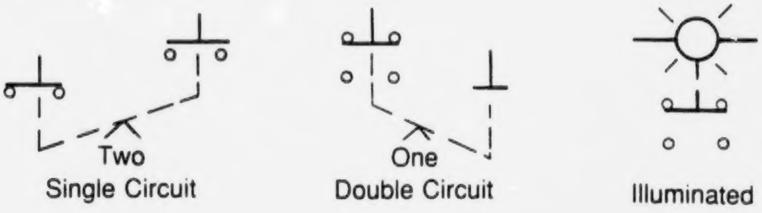


Information Sheet

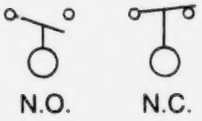
k. Momentary contacts


N.O.
N.C.
Single Circuit
N.O. and N.C.
Double Circuit
Mushroom
Head
Wobble
Stick

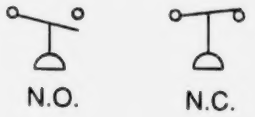
l. Maintained contacts


Two
Single Circuit
One
Double Circuit
Illuminated

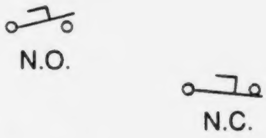
m. Liquid level switch



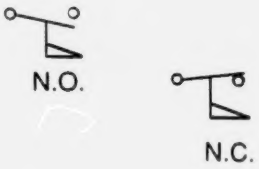
n. Pressure and vacuum switches



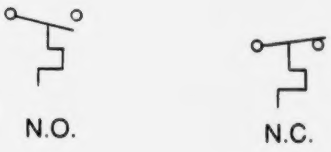
o. Foot switches



p. Flow switch

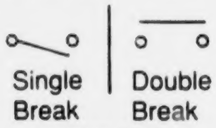


q. Temperature-actuated switch

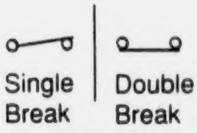


Information Sheet

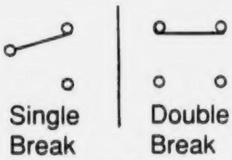
r. Switches


Single
Break
Double
Break

SPST N.O.


Single
Break
Double
Break

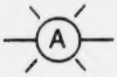
SPST N.C.


Single
Break
Double
Break

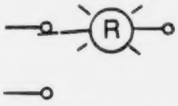
SPDT

s. Pilot lights

Note: Indicate color by letter.



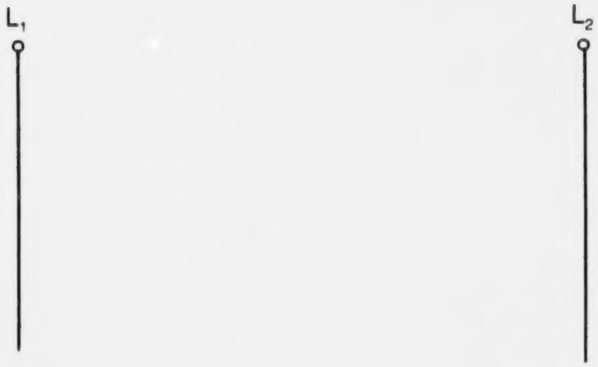
Non-Push-to-Test



Push-to-Test

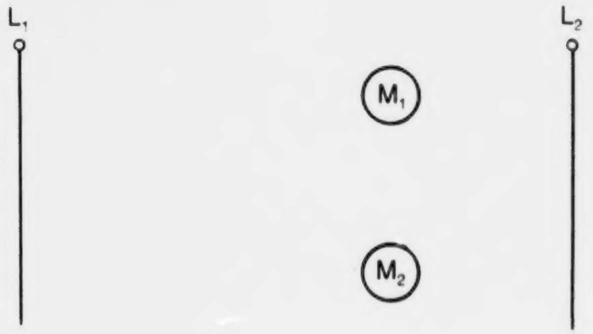
6. Major steps in constructing ladder diagrams

a. Establish and label power lines.

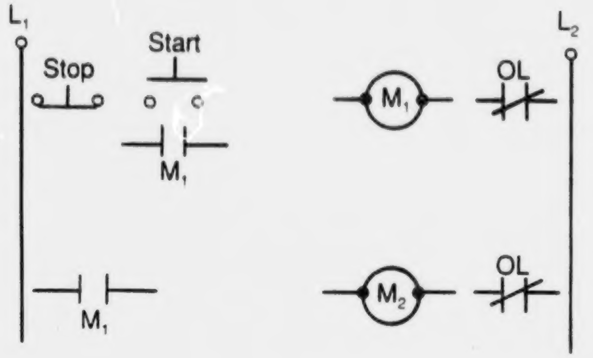


Information Sheet

b. Identify and label loads.

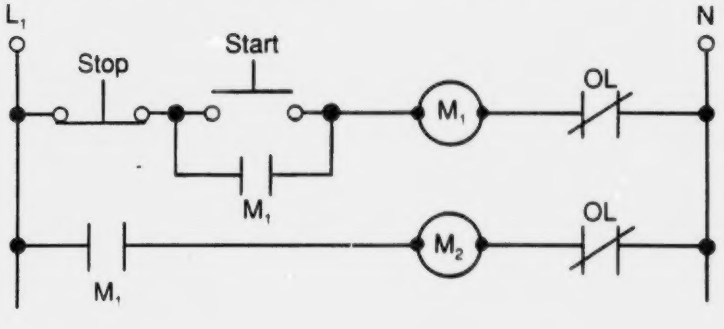


c. Identify and label control devices and contacts for each circuit (rung).



L1
L2
Stop
Start
M1
OL
M1
M1
M2
OL

d. Connect circuit wires, keeping ladder rungs equidistant for ease of reading.

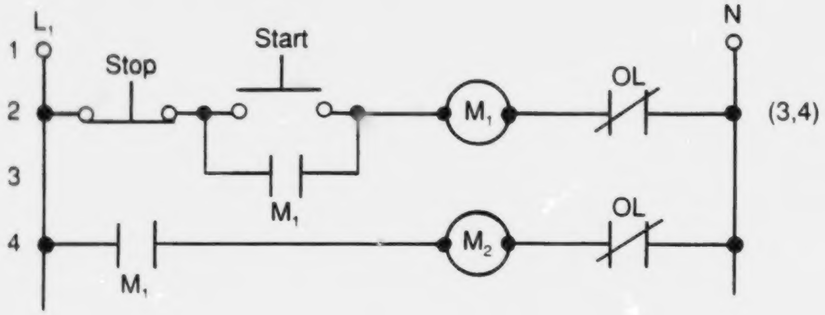


L1
N
Stop
Start
M1
OL
M1
M2
OL
M1

Information Sheet

e. Number rungs, and cross reference.

Note: This step is extremely important, especially in more complex diagrams containing many rungs.


L_1
N
1
2
3
4
Stop
Start
M_1
OL
(3,4)
M_1
OL
M_2
M_1

Electrical Diagrams and Symbols
Unit 8

Assignment Sheet 1—Construct a Basic Ladder Diagram

Name ______________________ Overall Rating __________

Evaluation Criteria	**Rating**
Diagram legibly drawn	______
All components correctly labeled	______
Directions followed exactly	______

Directions: The electrical technician must be able to draw and read ladder diagrams to facilitate troubleshooting procedures. In the space provided below, draw, label, and reference a ladder diagram with the following components: 120 VAC fused power supply, three loads, two single-pole single-throw (SPST) switches, and one control relay with a line voltage coil. Each load is to be a parallel circuit. Control two loads with the relay, one load with an SPST switch, and the relay coil with an SPST switch. The above criteria will be used to evaluate your performance.

Electrical Diagrams and Symbols
Unit 8

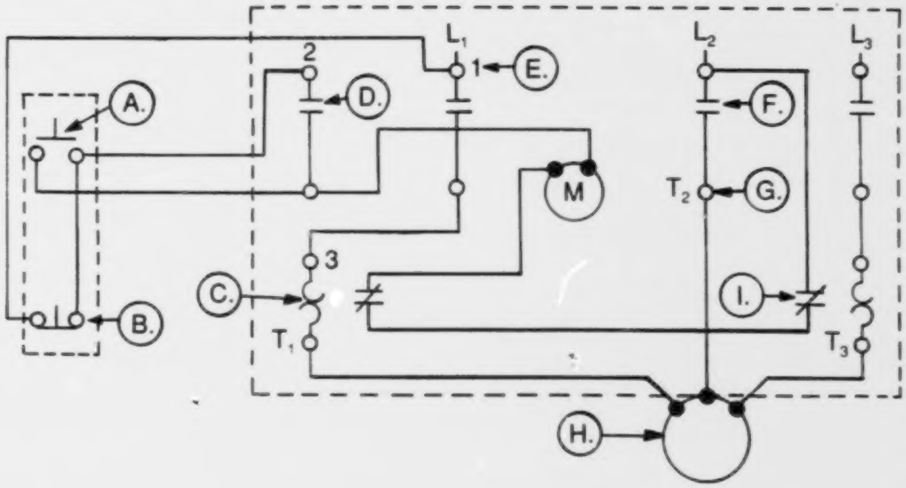
Assignment Sheet 2—Identify Electrical Symbols in a Wiring Diagram

Name ______________________________ Overall Rating __________

Evaluation Criteria	**Rating**
Correct answers given	______
Legible handwriting	______

Directions: The electrical technician must be able to identify electrical symbols in a wiring diagram in order to recognize all component parts in a device or circuit. Identify the electrical symbols used in the wiring diagram illustrated below. Write the answers in the blanks on the next page. The above criteria will be used to evaluate your performance.

Line and control wiring terminal
Normally closed push button (stop)
Three-phase motor
Overload device switch
Normally open push button (start)
T_2 motor lead terminal
Auxiliary contact
Thermal overload relay
Main contact



Assignment Sheet 2

A. ______________________________

B. ______________________________

C. ______________________________

D. ______________________________

E. ______________________________

F. ______________________________

G. ______________________________

H. ______________________________

I. ______________________________

Two- and Three-Wire Controls
Unit 9

Objective Sheet

Unit Objective

After completing this unit, the student should be able interpret wiring and ladder diagrams related to two-wire and three-wire controls as well as wire these systems. The student should demonstrate these competencies by completing the assignment sheets and job sheets, and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to two- and three-wire controls with their correct definitions.
2. Identify typical two-wire pilot devices.
3. List advantages of two-wire controls.
4. State the basic rule for three-wire controls.
5. List advantages of three-wire controls.
6. Describe the operation of a two-wire control system.
7. Describe the operation of a three-wire control system.
8. Complete a ladder and a wiring diagram of a two-wire control using a thermal switch. (Assignment Sheet 1)
9. Draw a ladder diagram of a three-wire control with an "on" indicating pilot light. (Assignment Sheet 2)
10. Draw a ladder and a wiring diagram of a three-wire control with an "off" indicating pilot light. (Assignment Sheet 3)
11. Determine the number and size of conductors needed to operate a two-wire control system. (Assignment Sheet 4)
12. Determine the number and size of conductors needed to operate a three-wire control system. (Assignment Sheet 5)
13. Wire a two-wire control. (Job Sheet 1)

Objective Sheet

14. Wire two float switches to operate a starter (series connection). (Job Sheet 2)

15. Wire two float switches to operate a starter (parallel connections). (Job Sheet 3)

16. Wire a pressure switch to operate a starter with "on" and "off" pilot lights. (Job Sheet 4)

17. Wire a three-wire control system. (Job Sheet 5)

18. Wire a multiple station three-wire control. (Job Sheet 6)

19. Wire a multiple station three-wire control with "on" and "off" pilot lights. (Job Sheet 7)

Two- and Three-Wire Controls
Unit 9

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan for students with special needs.
4. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.
5. Develop teaching plan. Adjust for different learning styles.
6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.
8. Discuss unit and specific objectives.
9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
10. Discuss the assignment and job sheets. Review criteria for evaluation of these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.
12. Make copies of the written test. Add or modify test items as needed.
13. Give written test.
14. Record assignment sheet ratings, job sheet ratings, and written test scores on the Unit Evaluation Form. Add any additional assignments or supplemental activities that should be part of the unit evaluation.

Suggested Activities

15. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Tour an industrial facility utilizing two-wire and three-wire controls. Discuss with the class observations made during the tour. Skill areas: **listening** and **oral communication**.
2. Show students various two-wire pilot devices.
3. Invite an industrial maintenance technician to speak to the class. Conduct a question and answer session following the presentation. Skill areas: **listening** and **oral communication**.
4. Contact a local Bussmann representative to obtain copies of motor control materials, or write to Bussmann Division, Cooper Industries, Inc., 210 Redstone Hill Rd., Bristol, CT 06010. Telephone: 203/582-6321.
5. Write to Square D for copies of their product information. Square D Company, 1415 So. Roselle, Palatine, IL 60067. Telephone: 708/397-2600.

Resources Used in Developing This Unit

1. Alerich, Walter N. *Electric Motor Control*, 4th Ed. Albany, NY: Delmar Publishers, Inc., 1988.
2. Kaltwasser, Stan and Gary Flowers. *Commercial and Industrial Wiring*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1988.
3. *National Electrical Code 1993*. Quincy, MA: National Fire Protection Association, 1992.
4. *Overcurrent Protection and the 1987 NEC*. St. Louis, MO: Bussmann, Cooper Industries, Inc. Bulletin NE-87.

Suggested Activities

Suggested Supplemental Resources

1. Croft, Terrell and Wilford I. Summers. *American Electrician's Handbook*. 11th Ed. New York: McGraw-Hill Book Company, 1987.

2. Earley, Mark W., John M. Caloggero and Richard H. Murray. *NEC Handbook 1993*. Quincy, MA: National Fire Protection Association, 1992.

3. O'Riley, Ronald P. *Illustrated Changes in the 1993 National Electrical Code*. Albany, NY: Delmar Publishers, Inc., 1993.

Instructions for Evaluating Student Performance

Assignment Sheets—Be sure the student understands the criteria on which the evaluation is based. Assign a point value to each criterion and convert the total points to a percentage for grading.

Job Sheets—Be sure the student understands the criteria on which the evaluation is based. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher edition or student manual. Then observe the student performing the procedure. Rate both process and product.

> Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.
>
> Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. Complete the rating by assigning a point value to each criterion and by converting the point total to a percentage for grading. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Suggested Activities

Sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) which best fits your program needs.

Option A

4 - Skilled—Can perform job with no additional training.
3 - Moderately skilled—Has performed job during training program; limited additional training may be required.
2 - Limited skill—Has performed job during training program; additional training is required to develop skill.
1 - Unskilled—Is familiar with process, but is unable to perform job.

Option B

Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

Two- and Three-Wire Controls
Unit 9

Answers to Assignment Sheets

Assignment Sheet 1 — Both diagrams should be complete and legibly drawn showing a two-wire control using a thermal switch.

Assignment Sheet 2 — The ladder diagram should show all components and be legibly drawn.

Assignment Sheet 3 — Both diagrams should be complete and legibly drawn showing a three-wire control with an "off" indicating pilot light and necessary auxiliary contacts.

Assignment Sheet 4

A. ½ inch EMT; 3 conductors; #12 or #14 AWG THWN
B. ½ inch EMT; 2 conductors; #12 or #14 AWG THWN
C. ½ inch EMT; 3 conductors; #12 or #14 AWG THWN
D. 10 amperes

Assignment Sheet 5

A. ½ inch EMT; 3 conductors; #12 AWG TW
B. ½ inch EMT; 4 conductors; #12 AWG THWN
C. ½ inch EMT; 7 conductors; #12 AWG TW
D. ½ inch EMT; 3 conductors; #12 AWG TW
E. 20 amperes

Two- and Three-Wire Controls
Unit 9

Answers to Written Test

1.
   - a. 7
   - b. 1
   - c. 2
   - d. 6
   - e. 3
   - f. 5
   - g. 4

2.
   - a. Pressure switch
   - b. Limit switch
   - c. Selector switch
   - d. Thermal switch
   - e. Flow switch
   - f. Toggle switch
   - g. Float switch

3.
   - a. Provide low voltage release
   - b. Do not require a human operator

4. Stop buttons are in series with auxiliary contacts and start buttons are in parallel with auxiliary contacts.

5.
   - a. Provide low voltage protection
   - b. Allow for easy installation of indicating pilot lights

6. When the two-wire device is closed through some type of mechanical action, it allows current to flow to the starter's coil, energizing the coil and causing the starter to close.

7. When start button is depressed, current flows to the coil where the armature pulls in, closes auxiliary contacts, and seals around the start button.

Two- and Three-Wire Controls
Unit 9

Written Test

Name ______________________________ Score ______________

1. Match the terms on the right with their correct definitions.

_____a. Any type of switch having definite "on" and "off" positions that is used to control a magnetic starter or contactor

_____b. Set of normally open or normally closed contacts on a starter, contactor or relay that close or open when main contacts close or open

_____c. Small light that indicates status of controls or machinery

_____d. Uses momentary contact; start/stop stations and a memory circuit interlock, connected in parallel with the start button to maintain the circuit

_____e. Magnetic control only; nonautomatic restarting; three-wire control; power failure disconnects service; power restored by manual restart

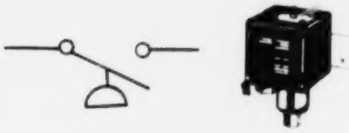
_____f. Directs operation of another device; alters the electrical circuit

_____g. Manual and magnetic control; automatic restarting; two-wire control; power failure disconnects service; when power is restored, the controller automatically restarts motor

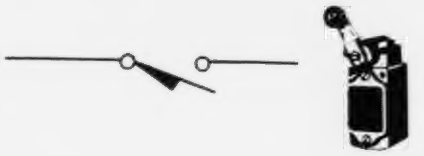
1. Auxiliary contacts
2. Indicating pilot light
3. Low voltage protection
4. Low voltage release
5. Pilot device
6. Three-wire control
7. Two-wire control

Written Test

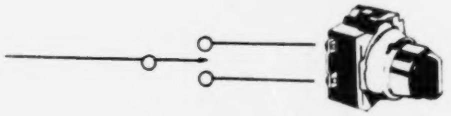
2. Identify the typical two-wire pilot devices shown below.



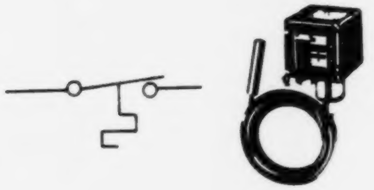
a. ______________________________



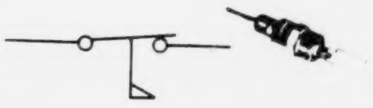
b. ______________________________



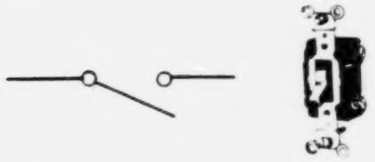
c. ______________________________



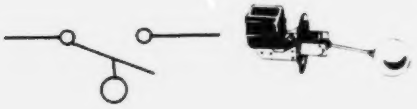
d. ______________________________



e. ______________________________



f. ______________________________



g. ______________________________

Written Test

3. List two advantages of two-wire controls.

   a. ______________________________

   b. ______________________________

4. State the basic rule for three-wire controls.

   ____

   ____

5. List two advantages of three-wire controls.

   a. ______________________________

   b. ______________________________

6. Describe the operation of a two-wire control system.

   ____

   ____

   ____

   ____

7. Describe the operation of a three-wire control system.

   ____

   ____

   ____

   ____

*Permission to duplicate this test is granted.

Two- and Three-Wire Controls
Unit 9

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Assignment Sheet 1—Complete a Ladder and a Wiring Diagram of a Two-Wire Control Using a Thermal Switch Rating ______

Comments: ____

____

Assignment Sheet 2—Draw a Ladder Diagram of a Three-Wire Control with an "On" Indicating Pilot Light Rating ______

Comments: ____

____

Assignment Sheet 3—Draw a Ladder and a Wiring Diagram of a Three-Wire Control with an "Off" Indicating Pilot Light Rating ______

Comments: ____

____

Assignment Sheet 4—Determine the Number and Size of Conductors Needed to Operate a Two-Wire Control System Rating ______

Comments: ____

____

Assignment Sheet 5—Determine the Number and Size of Conductors Needed to Operate a Three-Wire Control System Rating ______

Comments: ____

____

Job Sheet 1—Wire a Two-Wire Control Rating ______

Comments: ____

____

Unit Evaluation Form

Job Sheet 2—Wire Two Float Switches to Operate a Starter (Series Connection) Rating ______

Comments: ______________________________

____

Job Sheet 3—Wire Two Float Switches to Operate a Starter (Parallel Connections) Rating ______

Comments: ______________________________

____

Job Sheet 4—Wire a Pressure Switch to Operate a Starter with "On" and "Off" Pilot Lights Rating ______

Comments: ______________________________

____

Job Sheet 5—Wire a Three-Wire Control System Rating ______

Comments: ______________________________

____

Job Sheet 6—Wire a Multiple Station Three-Wire Control Rating ______

Comments: ______________________________

____

Job Sheet 7—Wire a Multiple Station Three-Wire Control with "On" and "Off" Pilot Lights Rating ______

Comments: ______________________________

____

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ______________________________

____

Teacher Signature ______________________ Date __________

Student Signature ______________________ Date __________

***Permission to duplicate this form is granted.**

Two- and Three-Wire Controls
Unit 9

Information Sheet

1. **Terms and definitions**

   a. **Auxiliary contacts** — Set of normally open or normally closed contacts on a starter, contactor, or relay that close or open when main contacts close or open

   b. **Indicating pilot light** — Small light that indicates status of controls or machinery

   c. **Low voltage protection** — Magnetic control only; nonautomatic restarting; three-wired control; power failure disconnects service; power restored by manual restart

   d. **Low voltage release** — Manual and magnetic control; automatic restarting; two-wire control; power failure disconnects service; when power is restored the controller automatically restarts motor

   e. **Pilot device** — Directs operation of another device; alters the electrical circuit

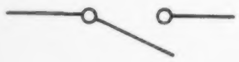
   f. **Three-wire control** — Uses momentary contact; start/stop stations and a memory circuit interlock connected in parallel with the start button to maintain the circuit

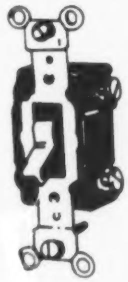
   g. **Two-wire control** — Any type of switch having definite "on" and "off" positions that is used to control a magnetic starter or contactor

2. **Typical two-wire pilot devices**

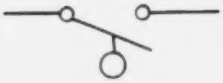
   Note: There are many different pilot devices. These are the most common.

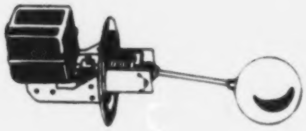
   a. Toggle switch



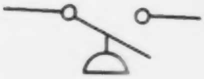


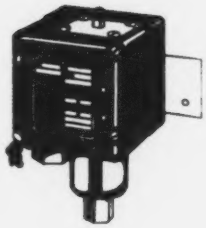
b. Float switch



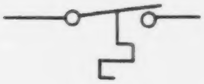


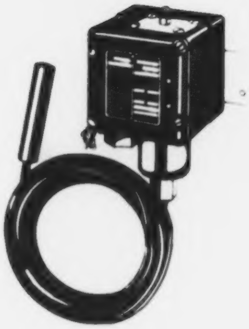
c. Pressure switch



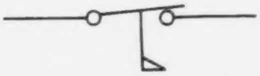


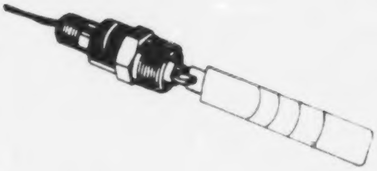
d. Thermal switch





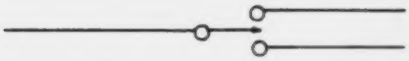
e. Flow switch

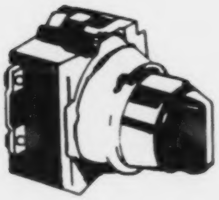




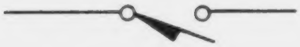
Information Sheet

f. Selector switch





g. Limit switch



3. **Advantages of two-wire controls**

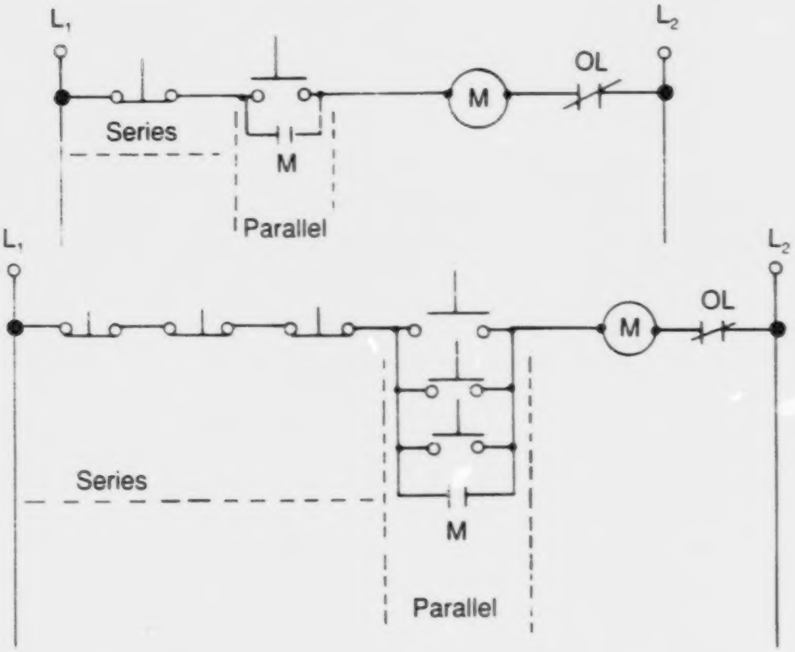
    a. Provide low voltage release

    b. Do not require a human operator

Information Sheet

4. **Basic rule for three-wire controls —** Stop buttons are in series with auxiliary contacts and start buttons are in parallel with auxiliary contacts.

   Note: This rule will apply no matter how many start/stop stations are used.


L1
L2
OL
M
Series
M
Parallel
L1
L2
OL
M
Series
M
Parallel

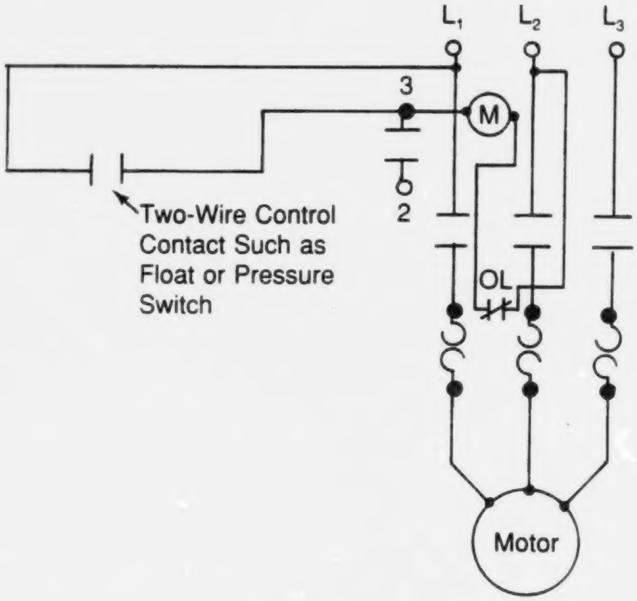
5. **Advantages of three-wire controls**
   a. Provide low voltage protection

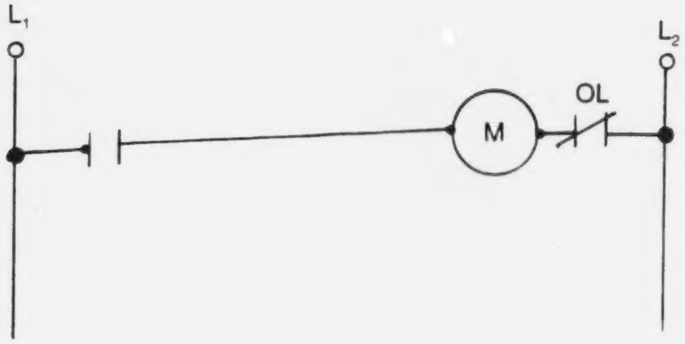
      Note: This protects both the operator and the equipment.

   b. Allow for easy installation of indicating pilot lights

Information Sheet

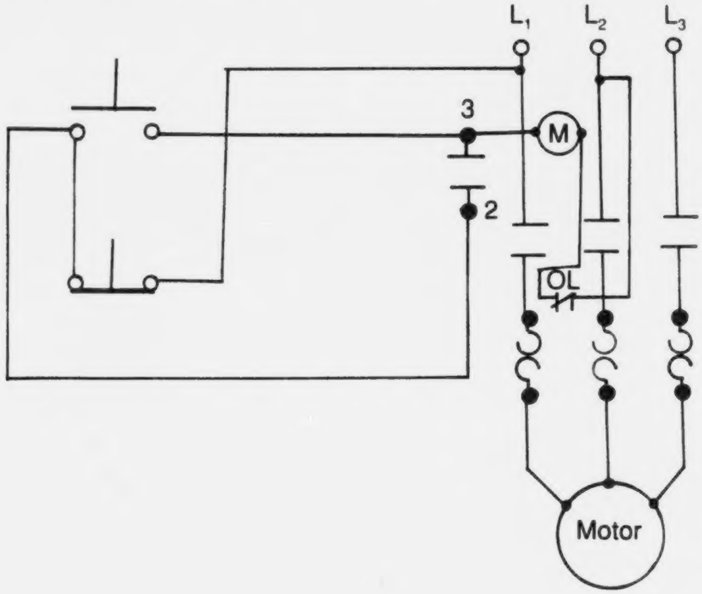
6. **Operation of a two-wire control system** — When the two-wire device is closed through some type of mechanical action, it allows current to flow to the starter's coil, energizing the coil and causing the starter to close.

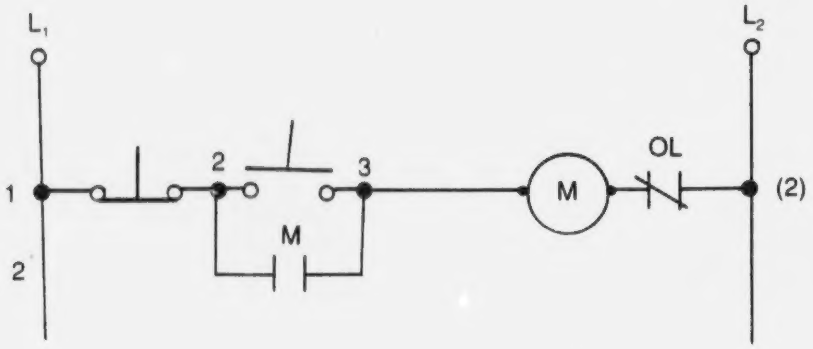

L1
L2
L3
3
M
2
Two-Wire Control Contact Such as Float or Pressure Switch
OL
Motor



Information Sheet

7. **Operation of a three-wire control system** — When the start button is depressed, current is allowed to flow to the magnetic coil, energizing the coil. When the coil energizes the magnetic field, it pulls the armature toward it, closing the main contacts. As the armature closes, it also mechanically closes the auxiliary contacts (memory contacts), giving the current a path around the start button and keeping the coil energized. When the stop button is depressed, the flow of current is interrupted, allowing the magnetic field to dissipate.





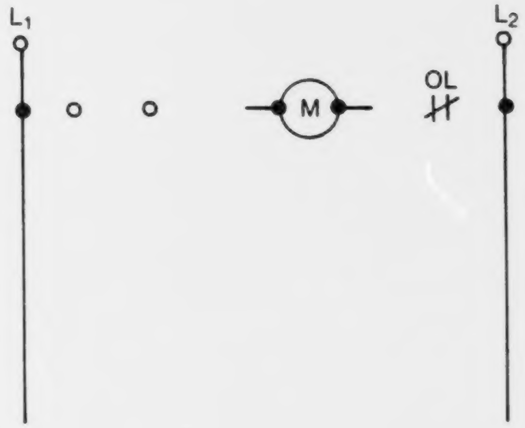
Two- and Three-Wire Controls
Unit 9

Assignment Sheet 1—Complete a Ladder and a Wiring Diagram of a Two-Wire Control Using a Thermal Switch

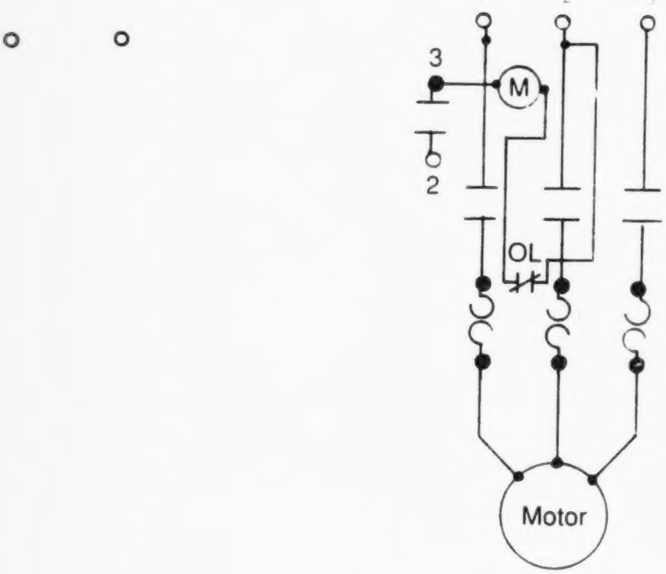
Name ______________________ Overall Rating __________

Evaluation Criteria	Rating
Legibly drawn	_____
Correct symbols used	_____
Accurate depiction in ladder diagram	_____
Accurate depiction in wiring diagram	_____

Directions: Complete the ladder and wiring diagrams below, using a thermal switch. The above criteria will be used to evaluate your performance.



Assignment Sheet 1


L1
L2
L3
3
M
2
OL
Motor

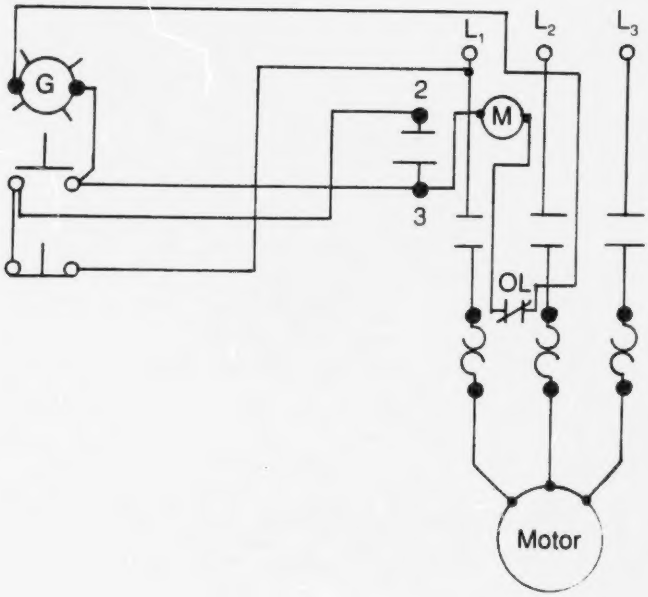
Two- and Three-Wire Controls
Unit 9

Assignment Sheet 2—Draw a Ladder Diagram of a Three-Wire Control With an "On" Indicating Pilot Light

Name ______________________________ Overall Rating __________

Evaluation Criteria	**Rating**
Legibly drawn	______
Correct symbols used	______
Accurate conversion to ladder diagram	______

Directions: Convert the following wiring diagram to a ladder diagram. The above criteria will be used to evaluate your performance.



Two- and Three-Wire Controls
Unit 9

Assignment Sheet 3—Draw a Ladder and a Wiring Diagram of a Three-Wire Control With an "Off" Indicating Pilot Light

Name ______________________________ Overall Rating __________

Evaluation Criteria	Rating
Legibly drawn	______
Correct symbols used	______
Accurate depiction in wiring diagram	______
Accurate depiction in ladder diagram	______

Directions: Draw a ladder and a wiring diagram of a three-wire control with an "off" indicating pilot light in the space provided below. The above criteria will be used to evaluate your performance.

Note: In order to operate the pilot light correctly, an additional set of normally closed auxiliary contacts must be added.

Two- and Three-Wire Controls
Unit 9

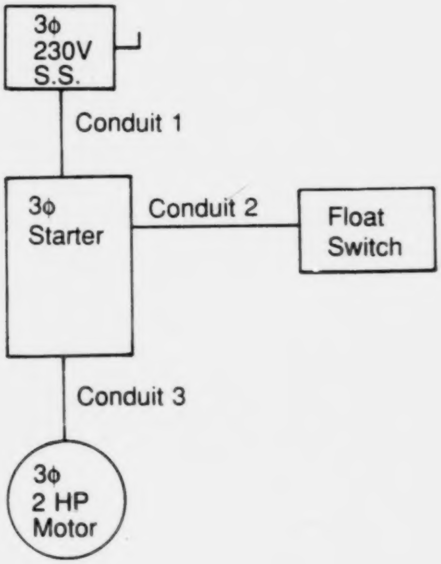
Assignment Sheet 4—Determine the Number and Size of Conductors Needed to Operate a Two-Wire Control System

Name ______________________________ Overall Rating __________

Evaluation Criteria	Rating
Ability to use *NEC*	_____
Ability to "read" drawing	_____
Correct answers given	_____

Directions: Using the drawing below and the *NEC*, determine the number of power and control conductors needed to operate the system. You must also determine the proper size conduit and the proper fuse size (dual element, time delay). The above criteria will be used to evaluate your performance.

Note: It may simplify the conductor count to draw a wiring diagram of this system.


3ϕ
230V
S.S.
Conduit 1
3ϕ
Starter
Conduit 2
Float
Switch
Conduit 3
3ϕ
2 HP
Motor

Assignment Sheet 4

A. Conduit 1 ________ inch EMT; ________ conductors; ________ AWG THWN

B. Conduit 2 ________ inch EMT; ________ conductors; ________ AWG THWN

C. Conduit 3 ________ inch EMT; ________ conductors; ________ AWG THWN

D. Dual element time delay fuse size= ________ amperes

Two- and Three-Wire Controls
Unit 9

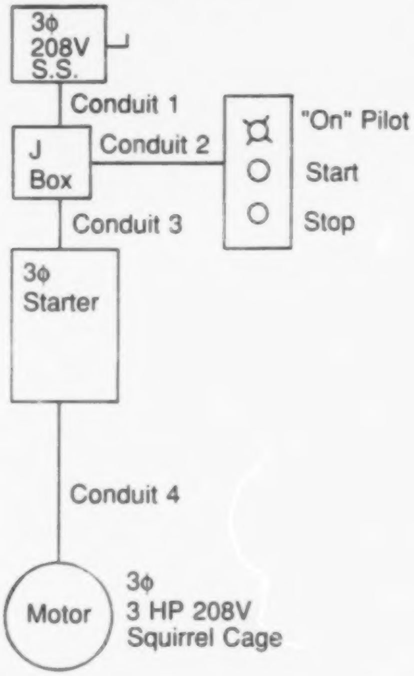
Assignment Sheet 5—Determine the Number and Size of Conductors Needed to Operate a Three-Wire Control System

Name ______________________________ Overall Rating __________

Evaluation Criteria	**Rating**
Ability to use *NEC*	_____
Ability to "read" drawing	_____
Correct answers given	_____

Directions: Using the drawing below and the *NEC*, determine the number of power and control conductors needed to operate the system. You must also determine the proper size conduit and the proper fuse size (dual element, time delay). The above criteria will be used to evaluate your performance.

Note: This starter has a line voltage coil.


3ϕ
208V
S.S.
Conduit 1
J
Box
Conduit 2
"On" Pilot
Start
Stop
Conduit 3
3ϕ
Starter
Conduit 4
Motor
3ϕ
3 HP 208V
Squirrel Cage

Assignment Sheet 4

A. Conduit 1 _________ inch EMT; _________ conductors; _________ AWG TW

B. Conduit 2 _________ inch EMT; _________ conductors; _________ AWG THWN

C. Conduit 3 _________ inch EMT; _________ conductors; _________ AWG TW

D. Conduit 4 _________ inch EMT; _________ conductors; _________ AWG TW

E. Dual element time delay fuse size= _________ amperes

Two- and Three-Wire Controls
Unit 9

Job Sheet 1—Wire a Two-Wire Control

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Ladder diagram correct	______
Wiring diagram correct	______
Sequence of operation correct	______
Equipment mounted properly	______
System operates	______
Demonstrated good workmanship	______
Complied to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
Three-phase open starter
Five feet #14 THHN
Mounting board
Four #10 x 1" sheet metal screws
Float switch (momentary N/O push button, to simulate action of float switch)

Job Sheet 1

B. Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a ladder and a wiring diagram of your system in the space provided below.

☐ 4. Have your instructor approve your drawings.

☐ 5. In complete sentences, describe the sequence of operation of the system.

____

____

____

____

____

____

____

Job Sheet 1

☐ 6. Mount the equipment.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate the job.

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's comments: ______________________________

____

____

Two- and Three-Wire Controls
Unit 9

Job Sheet 2—Wire Two Float Switches to Operate a Starter (Series Connection)

Name ________________________________ Attempt Number ________

Date ________________________________ Overall Rating ________

Evaluation Criteria	Rating
Practiced safety rules throughout procedure	______
Ladder diagram correct	______
Wiring diagram correct	______
Sequence of operation correct	______
Equipment mounted properly	______
System operates	______
Demonstrated good workmanship	______
Complied to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
Three-phase open starter
Five feet #14 THHN
Mounting board
Four #10 x 1" sheet metal screws
Two float switches (momentary N/O push button, to simulate action of float switch)

Job Sheet 2

B. Procedure

Note: Both switches must be activated in order for the starter to energize.

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a ladder and a wiring diagram of your system in the space provided below.

☐ 4. Have your instructor approve your drawings.

☐ 5. In complete sentences, describe the sequence of operation of the system.

Job Sheet 2

☐ 6. Mount the equipment.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate the job.

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's comments: ______________________________

____

____

Two- and Three-Wire Controls
Unit 9

Job Sheet 3—Wire Two Float Switches to Operate a Starter (Parallel Connections)

Name ______________________________ Attempt Number ________

Date ______________ ______________ Overall Rating __________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Ladder diagram correct	______
Wiring diagram correct	______
Sequence of operation correct	______
Equipment mounted properly	______
System operates	______
Demonstrated good workmanship	______
Complied to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
Three-phase open starter
Six feet #14 THHN
Mounting board
Four #10 x 1″ sheet metal screws
Two float switches (momentary N/O push button, to simulate action of float switch)

Job Sheet 3

B. Procedure

Note: Either switch will energize the starter.

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a ladder and a wiring diagram of your system in the space provided below.

☐ 4. Have your instructor approve your drawings.

☐ 5. In complete sentences, describe the sequence of operation of the system.

Job Sheet 3

☐ 6. Mount the equipment.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate the job.

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's comments: ____________________

____

____

Two- and Three-Wire Controls
Unit 9

Job Sheet 4—Wire a Pressure Switch to Operate a Starter with "On" and "Off" Pilot Lights

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	____
Ladder diagram correct	____
Wiring diagram correct	____
Sequence of operation correct	____
Equipment mounted properly	____
System operates	____
Demonstrated good workmanship	____
Complied to *NEC*	____

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
Three-phase open starter (with additional N/C auxiliary contacts)
Six feet #14 THHN
Ten #10 x 1" sheet metal screws
Pressure switch (momentary N/O push button, to simulate action of pressure switch)
Two 120 volt pilot lights

Job Sheet 4

B. Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a ladder and a wiring diagram of your system in the space provided below.

☐ 4. Have your instructor approve your drawings.

☐ 5. In complete sentences, describe the sequence of operation of the system.

____

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Job Sheet 4

- ☐ 6. Mount the equipment.
- ☐ 7. Wire the system.
- ☐ 8. Have your instructor evaluate the job.
- ☐ 9. Disassemble the system.
- ☐ 10. Return tools and materials to proper storage.
- ☐ 11. Clean the work area.

Evaluator's comments: ____

____

____

Two- and Three-Wire Controls
Unit 9

Job Sheet 5—Wire a Three-Wire Control System

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	_____
Ladder diagram correct	_____
Wiring diagram correct	_____
Sequence of operation correct	_____
Equipment mounted properly	_____
System operates	_____
Demonstrated good workmanship	_____
Complied to *NEC*	_____

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
Three-phase open starter
Six feet #14 THHN
Mounting board
Six #10 x 1″ sheet metal screws
Start/stop station (1-N/O push button, 1-N/C push button)

Job Sheet 5

B. Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a ladder and a wiring diagram of your system in the space provided below.

☐ 4. Have your instructor approve your drawings.

☐ 5. In complete sentences, describe the sequence of operation of the system.

____

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Job Sheet 5

☐ 6. Mount the equipment.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate the job.

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's comments: ______________________________

____

____

Two- and Three-Wire Controls
Unit 9

Job Sheet 6—Wire a Multiple Station Three-Wire Control

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation Criteria	Rating
Practiced safety rules throughout procedure	______
Ladder diagram correct	______
Wiring diagram correct	______
Sequence of operation correct	______
Equipment mounted properly	______
System operates	______
Demonstrated good workmanship	______
Complied to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
Three-phase open starter
Two start/stop stations
Eight #10 x 1″ sheet metal screws
Mounting board
Ten feet #14 THHN

Job Sheet 6

B. Procedure

Note: Stops are wired in series and starts are wired in parallel with the auxiliary contacts.

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a ladder and a wiring diagram of your system in the space provided below.

☐ 4. Have your instructor approve your drawings.

☐ 5. In complete sentences, describe the sequence of operation of the system.

Job Sheet 6

☐ 6. Mount the equipment.
☐ 7. Wire the system.
☐ 8. Have your instructor evaluate the job.
☐ 9. Disassemble the system.
☐ 10. Return tools and materials to proper storage.
☐ 11. Clean the work area.

Evaluator's comments: ____

____

____

Two- and Three-Wire Controls
Unit 9

Job Sheet 7—Wire a Multiple Station Three-Wire Control with "On" and "Off" Pilot Lights

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating __________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Ladder diagram correct	______
Wiring diagram correct	______
Sequence of operation correct	______
Equipment mounted properly	______
System operates	______
Demonstrated good workmanship	______
Complied to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
Three-phase open starter (extra N/C contacts)
Two start/stop stations
Two 120 volt pilot lights
Ten feet #14 THHN
Twelve #10 x 1″ sheet metal screws

Job Sheet 7

B. Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a ladder and a wiring diagram of your system in the space provided below.

☐ 4. Have your instructor approve your drawings.

☐ 5. In complete sentences, describe the sequence of operation of the system.

____

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Job Sheet 7

☐ 6. Mount the equipment.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate the job.

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's comments: ______________________________

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____

Separate Control Circuits
Unit 10

Objective Sheet

Unit Objective

After completing this unit, the student should be able to read and interpret diagrams and wire separate control circuits. The student should demonstrate these competencies by completing the assignment sheets and job sheets, and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to separate control circuits with their correct definitions.
2. List reasons for separate control circuits.
3. List applications for separate control circuits.
4. List sources of separate control circuits.
5. Match voltage ratings with their typical control transformer schematics.
6. Describe the necessary changes that must be made to a starter when using a separate control circuit.
7. Read and interpret ladder diagrams using separate control circuits. (Assignment Sheet 1)
8. Answer questions dealing with control circuits. (Assignment Sheet 2)
9. Determine the size and number of conductors needed to operate a separate control circuit. (Assignment Sheet 3)
10. Wire a relay and a load with a separate control circuit. (Job Sheet 1)
11. Wire a three-phase starter to operate by a separate control circuit. (Job Sheet 2)

Separate Control Circuits
Unit 10

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.

2. Review Teaching Suggestions section that follows. Plan for classroom activities.

3. Plan for students with special needs.

4. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.

5. Develop teaching plan. Adjust for different learning styles.

6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.

8. Discuss unit and specific objectives.

9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.

10. Discuss the assignment and job sheets. Review criteria for evaluation of these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

12. Make copies of the written test. Add or modify test items as needed.

13. Give written test.

14. Record assignment sheet and job sheet ratings and written test scores on the Unit Evaluation Form. Add any additional assignments or supplemental activities that should be part of the unit evaluation.

Suggested Activities

15. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Visit the machine tool lab to view separate control circuits in use on machines. Have students take notes and participate in a class discussion of their observations. Skill areas: **listening** and **oral communication**.
2. Visit a local industry that has a motor control center. Encourage students to ask about what they see. Skill areas: **listening** and **oral communication**.
3. Show students control transformers, time clocks, push-to-test lights, etc. Allow students to become familiar with these devices.

Resources Used in Developing This Unit

1. Alerich, Walter N. *Electric Motor Control*, 4th Ed. Albany, NY: Delmar Publishers, Inc., 1988.
2. Industrial Control Catalog, 1986-87. Milwaukee, WI: Cutler-Hammer, Eaton Corp., 1986.
3. Kaltwasser, Stan and Gary Flowers. *Commercial and Industrial Wiring*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1988.
4. *National Electrical Code 1993*. Quincy, MA: National Fire Protection Association, 1992.
5. *Square D Digest*. Palatine, IL: Square D Company, 1987.

Suggested Supplemental Resources

1. Croft, Terrell and Wilford I. Summers. *American Electrician's Handbook*, 11th Ed. New York: McGraw-Hill Book Company, 1987.
2. Earley, Mark W., John M. Caloggero and Richard H. Murray. *NEC Handbook 1993*. Quincy, MA: National Fire Protection Association, 1992.

Suggested Activities

3. O'Riley, Ronald P. *Illustrated Changes in the 1993 National Electrical Code.* Albany, NY: Delmar Publishers, Inc., 1993.

Instructions for Evaluating Student Performance

Assignment Sheets—Be sure the student understands the criteria on which the evaluation is based. Assign a point value to each criterion and convert the total points to a percentage for grading.

Job Sheets—Be sure the student understands the criteria on which the evaluation is based. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher edition or student manual. Then observe the student performing the procedure. Rate both process and product.

> Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.
>
> Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. Complete the rating by assigning a point value to each criterion and by converting the point total to a percentage for grading. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) which best fits your program needs.

Option A

4 - Skilled—Can perform job with no additional training.
3 - Moderately skilled—Has performed job during training program; limited additional training may be required.
2 - Limited skill—Has performed job during training program; additional training is required to develop skill.
1 - Unskilled—Is familiar with process, but is unable to perform job.

Option B

Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

Separate Control Circuits
Unit 10

Answers to Assignment Sheets

Assignment Sheet 1 — The correct sequence of operation for all three diagrams should be described.

Assignment Sheet 2

A. Yes — 430-72 Table, 430-72(b) Column C
B. No — 430-74(b)
C. No — 430-74(a), 430-102(a)
D. 500% — 430-72(c) Exception 2

Assignment Sheet 3

A. 3 conductors; #12 AWG
B. 2 conductors; #14 AWG
C. 2 conductors; #14 AWG
D. 3 conductors; #12 AWG
E. 15 amps
F. Correct answer dependent on selection charts used

Separate Control Circuits
Unit 10

Answers to Written Test

1. a. 3 d. 4
   b. 5 e. 6
   c. 1 f. 2

2. a. To step control voltage down to safe levels
   b. To match control voltage with control components' operating voltage

3. a. Air conditioning and heating equipment
   b. Motor control centers
   c. Pump control panels

4. a. Control transformer
   b. Separate 120 volt control with circuit disconnect

5. a. 2
   b. 1
   c. 3

6. Remove wire between L_2 and the coil.

Separate Control Circuits
Unit 10

Written Test

Name ______________________________ Score ____________

1. Match the terms on the right with their correct definitions.

   ______a. Large panel used in industrial applications to centrally locate motor starters, motor branch circuit short circuit and ground fault protective devices, and motor branch circuit disconnecting means

   ______b. An electromechanical or electronic switch designed to control electrical circuits and equipment based on preset times of day

   ______c. Small transformer used to step supply voltage down to appropriate control voltage

   ______d. Used to indicate "on" and "off" status of motor and to verify condition by means of indicating a burned out lamp

   ______e. Relay whose coils are connected between the line terminals of motor branch circuit: opens a set of N/O contacts if one or more phases is lost

   ______f. Device connected to the supply side of a system, designed to absorb transient surges

   1. Control transformer
   2. Lightning arrestor
   3. Motor control center
   4. Push-to-test pilot light
   5. Time clock
   6. Under voltage relay

2. List two reasons for separate control circuits.

   a. ____

   b. ____

Written Test

3. List three applications for separate control circuits.

   a. ______________________________

   b. ______________________________

   c. ______________________________

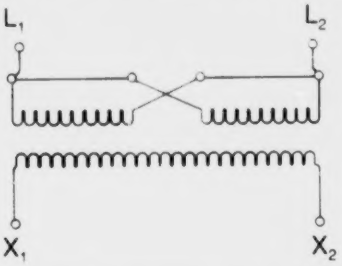
4. List two sources of separate control circuits.

   a. ______________________________

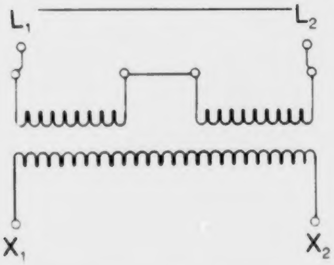
   b. ______________________________

5. Match the voltage ratings on the right with their typical control transformer schematics.

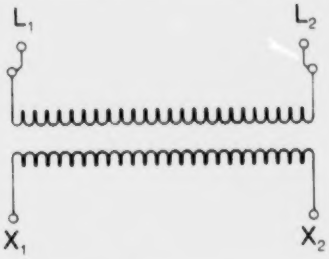
   1. 480/120
   2. 240/120
   3. 240/24



a. ______________



b. ______________



c. ______________

Written Test

6. Describe the necessary changes that must be made to a starter when using a separate control circuit.

*Permission to duplicate this test is granted.

Separate Control Circuits
Unit 10

Unit Evaluation Form

Student Name ______________________ Unit Rating ________

Assignment Sheet 1—Read and Interpret Ladder Diagrams Using Separate Control Circuits Rating ______

Comments: ______________________________

____

Assignment Sheet 2—Answer Questions Dealing with Control Circuits Rating ______

Comments: ______________________________

____

Assignment Sheet 3—Determine the Size and Number of Conductors Needed to Operate a Separate Control System Rating ______

Comments: ______________________________

____

Job Sheet 1—Wire a Relay and a Load with a Separate Control Circuit Rating ______

Comments: ______________________________

____

Job Sheet 2—Wire a Three-Phase Starter to Operate by a Separate Control Circuit Rating ______

Comments: ______________________________

____

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ______________________________

____

Teacher Signature ______________________ Date ________

Student Signature ______________________ Date ________

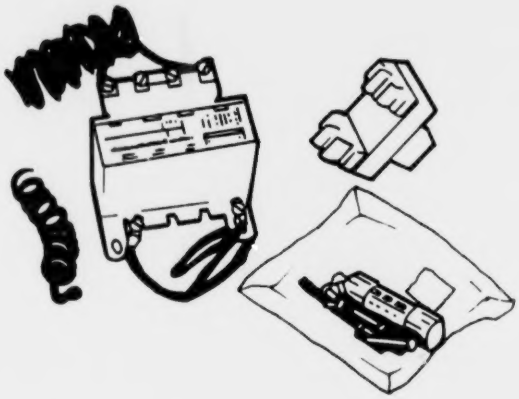
***Permission to duplicate this form is granted.**

Separate Control Circuits
Unit 10

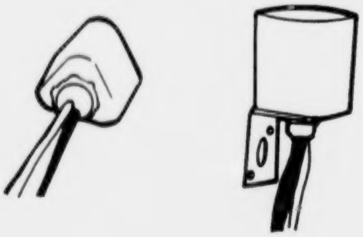
Information Sheet

1. **Terms and definitions**

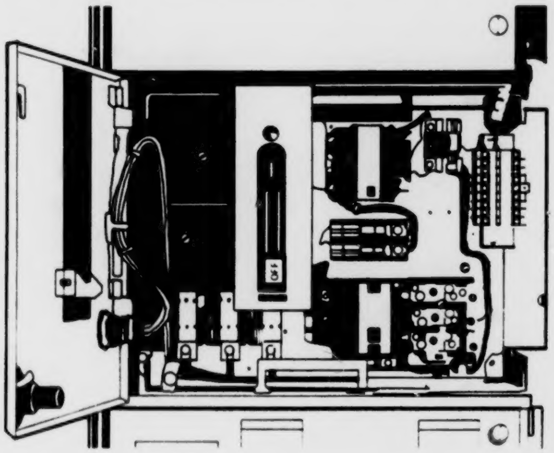
   a. **Control transformer** — Small transformer used to step supply voltage down to appropriate control voltage



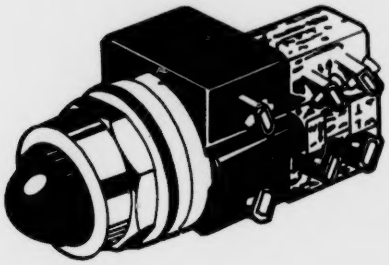
   b. **Lightning arrestor** — Device connected to the supply side of a system, designed to absorb transient surges

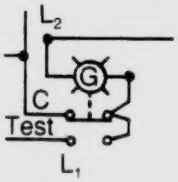


c. **Motor control center** — Large panel used in industrial applications to centrally locate motor starters, motor branch circuit short circuit and ground fault protective devices, and motor branch circuit disconnecting means



d. **Push-to-test pilot light** — Used to indicate "on" and "off" status of a motor and to verify condition by means of indicating a burned out lamp



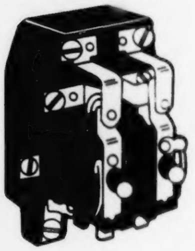


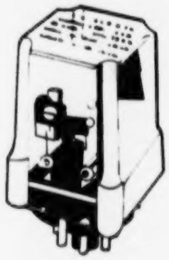
Information Sheet

e. **Time clock** — An electromechanical or electronic switch designed to control electrical circuits and equipment based on preset times of day

Note: There are many different types of time clocks. It is necessary to obtain the manufacturer's schematic to wire each type.

f. **Under voltage relay** — Relay whose coils are connected between the line terminals of a motor branch circuit; opens a set of N/O contacts if one or more phases is lost





2. **Reasons for separate control circuits**

Note: At times it may become necessary to operate pilot devices or push buttons at a lower voltage than the motor voltage. In such a case, a separate source, such as an isolating transformer or an independent voltage source may be used.

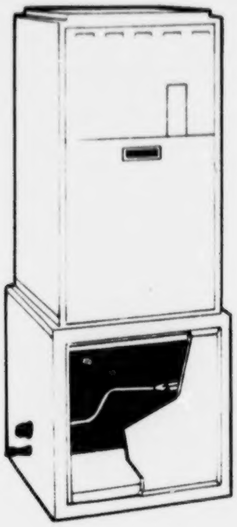
a. To step control voltage down to safe levels

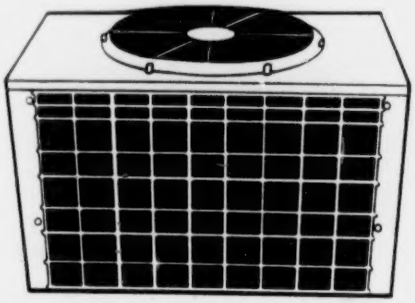
b. To match control voltage with control components' operating voltage

Information Sheet

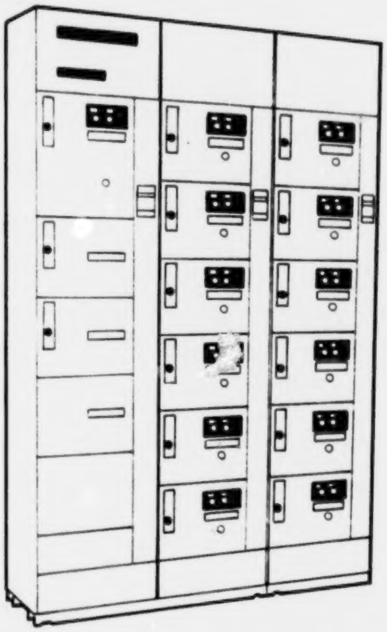
3. Applications for separate control circuits

a. Air conditioning and heating equipment





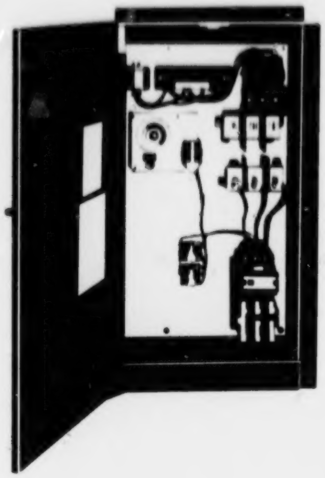
b. Motor control centers



Information Sheet

c. Pump control panels

Note: These units are extensively used in irrigation systems and oil field applications.



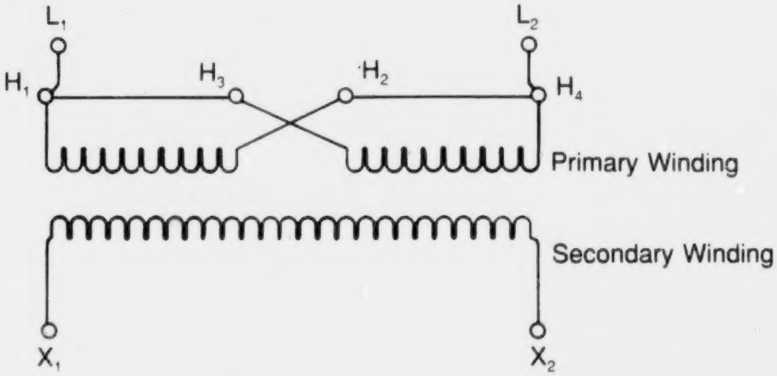
4. Sources of separate control circuits

a. Control transformer

b. Separate 120 volt control with circuit disconnect

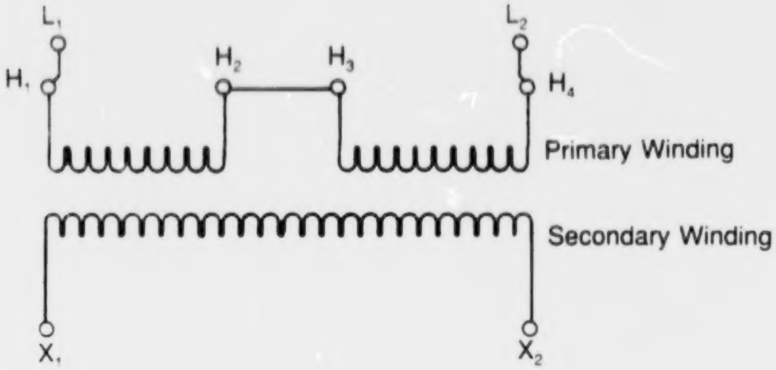
5. Typical control transformer schematics and their voltage ratings

a. 240 primary; 120 secondary


L_1
L_2
H_1
H_3
H_2
H_4
Primary Winding
Secondary Winding
X_1
X_2

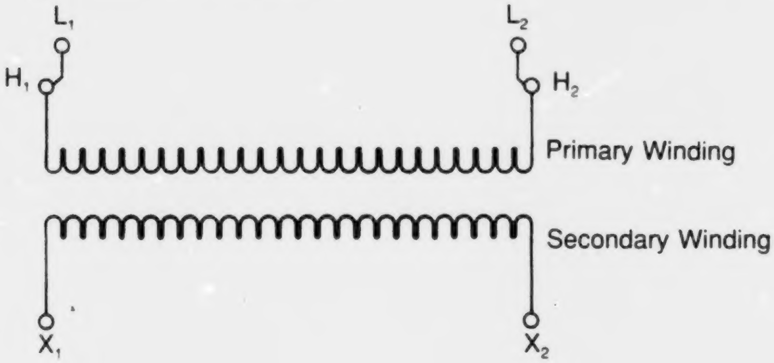
Information Sheet

b. 480 primary; 120 secondary


L1
L2
H1
H2
H3
H4
Primary Winding
Secondary Winding
X1
X2

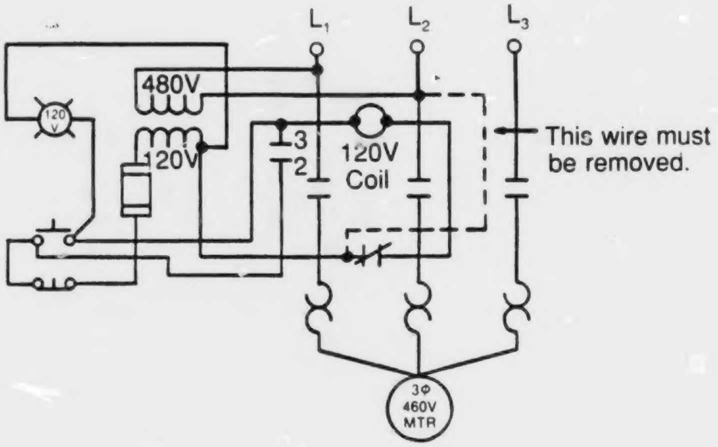
Note: It is important to connect the primary taps correctly to match the input voltage.

c. 240 primary; 24 secondary


L1
L2
H1
H2
Primary Winding
Secondary Winding
X1
X2

Information Sheet

6. **Necessary changes that must be made to a starter when using a separate control circuit** — When operating three-phase starters on a separate control source, it is necessary to remove any and all wires that connect from the line terminals to any portion of the control circuitry. Specifically the wire that is connected from L_2 to the coil must be removed.



L1
L2
L3
480V
120V
120 V
3
2
120V Coil
This wire must be removed.
3Φ 460V MTR

Separate Control Circuits
Unit 10

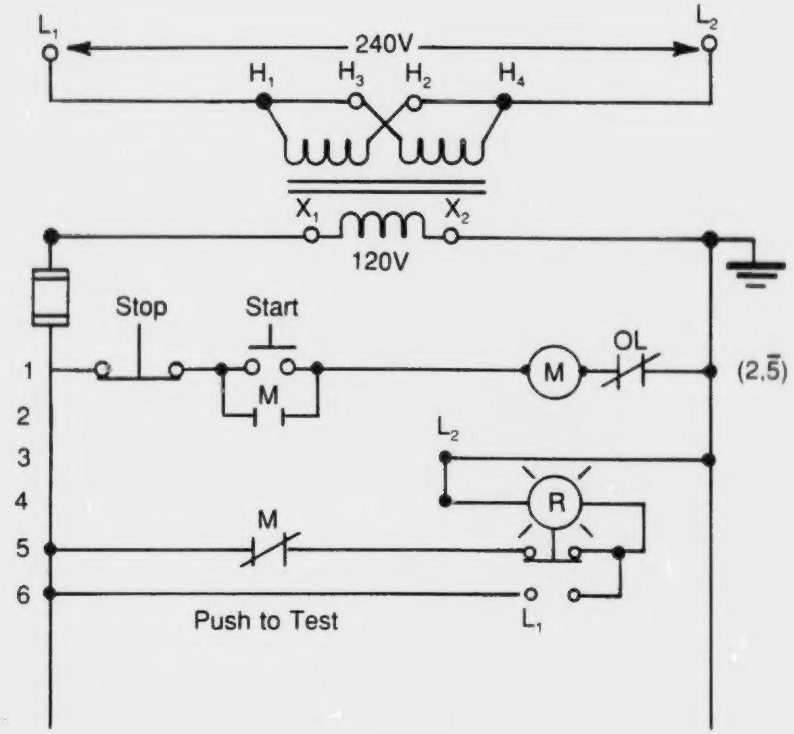
Assignment Sheet 1—Read and Interpret Ladder Diagrams Using Separate Control Circuits

Name ______________________________ Overall Rating __________

Evaluation Criteria	**Rating**
Correct sequence of operation given	_____
Answers legibly written	_____

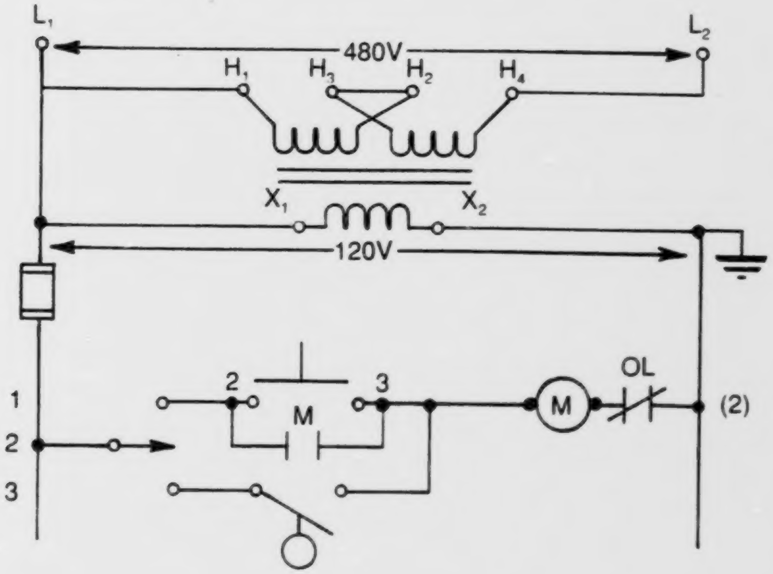
Directions: Read the following ladder diagrams and describe the sequence of operation in the space provided. The above criteria will be used to evaluate your performance.

A.


L1
240V
L2
H1
H3
H2
H4
X1
X2
120V
Stop
Start
1
M
M
OL
(2,5̄)
2
L2
3
4
R
M
5
6
Push to Test
L1

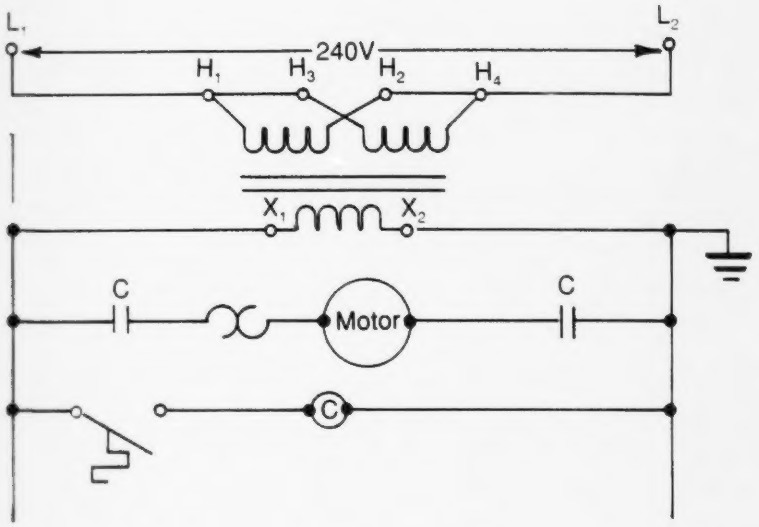
Assignment Sheet 1

B.


L1
L2
480V
H1
H3
H2
H4
X1
X2
120V
1
2
3
2
3
M
M
OL
(2)

Assignment Sheet 1

C.


L₁
L₂
240V
H₁
H₃
H₂
H₄
X₁
X₂
C
C
Motor
C

Separate Control Circuits
Unit 10

Assignment Sheet 2—Answer Questions Dealing with Control Circuits

Name ______________________________ Overall Rating __________

Evaluation Criteria	**Rating**
Correct use of the *NEC* demonstrated	______
Correct answers given	______

Directions: Using the *NEC*, answer the following questions that deal with control circuits. Specify the appropriate article number in the space provided. The above criteria will be used to evaluate your performance.

A. If the #16 AWG control circuit conductors extend beyond the control equipment enclosure and are tapped from the motor branch circuit, is supplementary fuse protection required if the motor branch circuit is fused at 60 amperes?

____

Article ______________________________

B. May a control transformer located within a motor controller enclosure be tapped from the line side of the disconnecting means?

____

Article ______________________________

C. May the motor control circuit disconnecting means be located in a separate room from the motor circuit disconnecting means?

____

Article ______________________________

D. What is the maximum percentage of rated primary current that an overcurrent device may be rated or set if the control circuit transformer rated primary current is less than 2 amperes?

____

Article ______________________________

Separate Control Circuits
Unit 10

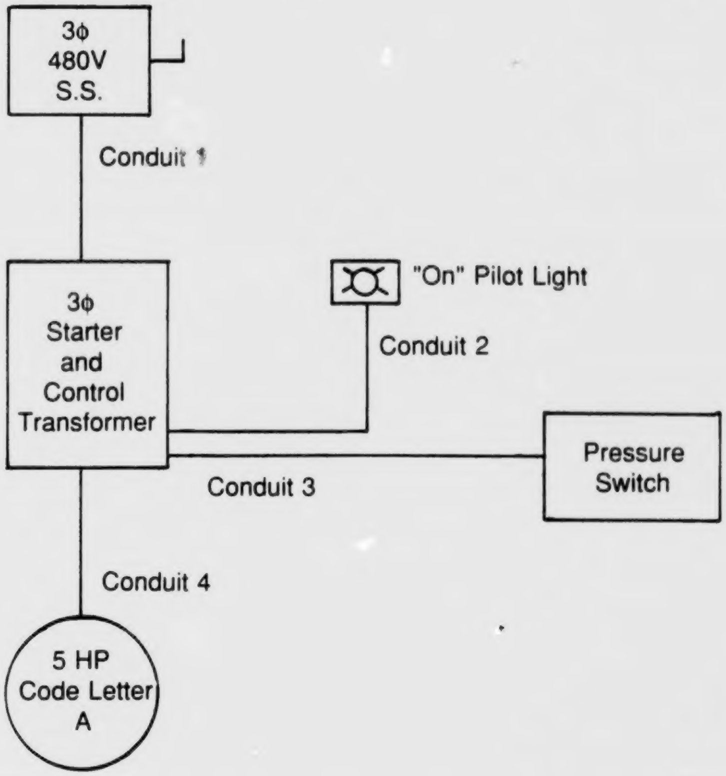
Assignment Sheet 3—Determine the Size and Number of Conductors Needed to Operate a Separate Control Circuit

Name ______________________________ Overall Rating __________

Evaluation Criteria	**Rating**
Correct use of the *NEC* demonstrated	______
Correct answers given	______

Directions: Using the *NEC* and additional materials supplied to you by your instructor, answer the questions following the diagram shown below. The above criteria will be used to evaluate your performance.

Note: Coil voltage is 120 volts.


3ϕ
480V
S.S.
Conduit 1
3ϕ
Starter
and
Control
Transformer
"On" Pilot Light
Conduit 2
Pressure
Switch
Conduit 3
Conduit 4
5 HP
Code Letter
A

Assignment Sheet 3

A. Conduit 1 _________ conductors; _________ AWG

B. Conduit 2 _________ conductors: _________ AWG

C. Conduit 3 _________ conductors; _________ AWG

D. Conduit 4 _________ conductors; _________ AWG

E. Fuse size _________ (Dual element time delay)

F. Heater amperes _________ part number _________

Separate Control Circuits
Unit 10

Job Sheet 1—Wire a Relay and a Load with a Separate Control Circuit

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Ladder diagram correct	______
Wiring diagram correct	______
System operates	______
Demonstrated good workmanship	______
Complied to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
Four pole relay with 24 volt coil (4 N/O)
120/24 volt transformer
Start/stop station
Mounting board
Eight #10 x 1″ sheet metal screws
Ten feet #16 TFF
Pilot light

Job Sheet 1

B. Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a ladder and a wiring diagram of a control system using one start/stop station to control a 4-pole relay. The relay will operate a 120 volt pilot light and will be actuated by 24 volts.

☐ 4. Have your instructor approve your drawings.

☐ 5. In complete sentences, describe the sequence of operation of your control system.

Job Sheet 1

☐ 6. Have your instructor approve your description.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate your work.

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's comments: ____

____

____

Separate Control Circuits
Unit 10

Job Sheet 2—Wire a Three-Phase Starter to Operate by a Separate Control Circuit

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Gave proper sequence description	______
System operates	______
Demonstrated good workmanship	______
Complied to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
3ϕ starter with 120 volt coil
240 volt (live) 3ϕ power source
480-240/120 control transformer
Fuse block
6/10 amp fuse
Mounting board
Three-position selector switch and enclosure
Twelve #10 x 1″ sheet metal screws
24 hour time clock with 120 volt timer motor
15 feet #14 THHN

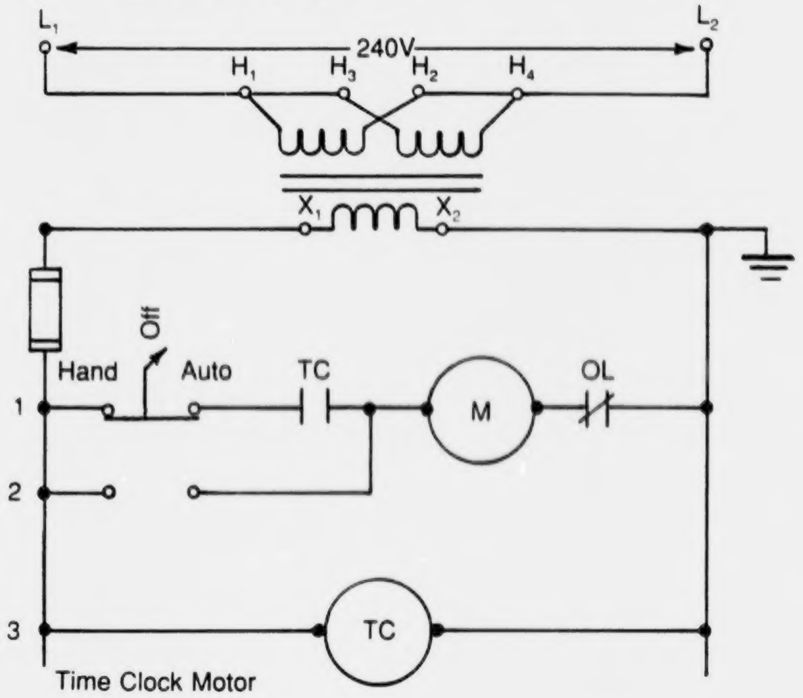
Job Sheet 2

B. Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Using the following ladder diagram, write a complete sequence of operation of the system.


L1
L2
240V
H1
H3
H2
H4
X1
X2
Off
Hand
Auto
TC
M
OL
1
2
3
TC
Time Clock Motor

Job Sheet 2

☐ 4. Have your instructor approve your sequence description.

☐ 5. Wire the system.

☐ 6. Have your instructor evaluate your work.

☐ 7. Disassemble the system.

☐ 8. Return tools and materials to proper storage.

☐ 9. Clean the work area.

Evaluator's comments: ______________________________

____

____

Sequence Control
Unit 11

Objective Sheet

Unit Objective

After completing this unit, the student should be able to read and interpret ladder diagrams dealing with sequence control and auxiliary contact interlocking and wire these types of applications. The student should demonstrate these competencies by completing the assignment and job sheets, and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to sequence control.
2. State the purpose of sequence control.
3. List advantages of sequence control.
4. List uses of sequence control.
5. State the purpose of auxiliary contact interlocking.
6. List advantages of auxiliary contact interlocking.
7. List uses of auxiliary contact interlocking.
8. Answer questions related to a sequence control diagram. (Assignment Sheet 1)
9. Answer questions related to an auxiliary contact interlocking diagram. (Assignment Sheet 2)
10. Wire two starters in sequence. (Job Sheet 1)
11. Wire two starters with auxiliary contact interlocking. (Job Sheet 2)

Sequence Control
Unit 11

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.

2. Review Teaching Suggestions section that follows. Plan for classroom activities.

3. Plan for students with special needs.

4. Obtain films, videotapes and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.

5. Develop teaching plan. Adjust for different learning styles.

7. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.

8. Discuss unit and specific objectives.

9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.

10. Discuss the assignment and job sheets. Review criteria for evaluation of these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

12. Make copies of the written test. Add or modify test items as needed.

13. Give written test.

14. Record assignment sheet and job sheet ratings and written test scores on the Unit Evaluation Form. Add any additional assignments or supplemental activities that should be part of the unit evaluation.

Suggested Activities

15. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Invite a local maintenance electrician to speak on the importance of sequencing and interlocking. Conduct a question and answer session after the talk. Skill areas: **listening** and **oral communication**.
2. Visit a supply house to view the various types of interlocking devices. Have students write a brief description of what they learned. Skill areas: **listening** and **writing**.

Resources Used in Developing This Unit

1. Alerich, Walter N. *Electric Motor Controls*, 4th Ed. Albany, NY: Delmar Publishers, Inc., 1988.
2. Kaltwasser, Stan and Gary Flowers. *Commercial and Industrial Wiring*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1988.
3. *National Electrical Code 1993*. Quincy, MA: National Fire Protection Association, 1992.

Suggested Supplemental Resources

1. Croft, Terrell and Wilford I. Summers. *American Electrician's Handbook*, 11th Ed. New York: McGraw-Hill Book Company, 1987.
2. Earley, Mark W., John M. Caloggero and Richard H. Murray. *NEC Handbook 1993*. Quincy, MA: National Fire Protection Association, 1992.
3. O'Riley, Ronald P. *Illustrated Changes in the 1993 National Electrical Code*. Albany, NY: Delmar Publishers, Inc., 1993.
4. Rexford, Kenneth B. *Electrical Control for Machines*, 3rd Ed. Albany, NY: Delmar Publishers, 1987.

Suggested Activities

Instructions for Evaluating Student Performance

Assignment Sheets—Be sure the student understands the criteria on which the evaluation is based. Assign a point value to each criterion and convert the total points to a percentage for grading.

Job Sheets—Be sure the student understands the criteria on which the evaluation is based. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher edition or student manual. Then observe the student performing the procedure. Rate both process and product.

> Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.
>
> Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. Complete the rating by assigning a point value to each criterion and by converting the point total to a percentage for grading. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) which best fits your program needs.

Option A

4 - Skilled—Can perform job with no additional training.
3 - Moderately skilled—Has performed job during training program; limited additional training may be required.
2 - Limited skill—Has performed job during training program; additional training is required to develop skill.
1 - Unskilled—Is familiar with process, but is unable to perform job.

Option B

Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

Sequence Control
Unit 11

Answers to Assignment Sheets

Assignment Sheet 1

A. (1) Coil M_1 energizes.
   (2) Contact M_1, Rung 2 closes, sealing in coil M_1 and energizing Rung 3.
   (3) Contact M_1, Rung 5 opens, de-energizing red light.

B. If coil M_1 is not energized, nothing will happen. This is due to the fact that the three-wire control feeds from terminal 3 on starter M_1. If coil M_1 has been energized, coil M_2 will energize. Contact M_2 on rung 4 will close. Contact M_2 on rung 6 will open killing the red pilot light.

C. (1) Coil M_2 de-energizes.
   (2) Contact M_2, Rung 4 opens.
   (3) Contact M_2, Rung 6 closes, energizing red light.

D. (1) Rungs 1, 2, 3, and 4 de-energize.
   (2) Contact M_1, Rung 2 and contact M_2, Rung 4 open.
   (3) Contact M_1, Rung 5 and contact M_2, Rung 6 close and red lights energize.

E. No. Power will not flow to Rung 3 unless coil M_1 is energized.

Assignment Sheet 2

A. Nothing happens because N/O contact M_1 is open.

B. Rungs 13, 14, 15, and 16. They are "off" indicators.
C. Yes, because N/O interlocking on Rung 10 is operated by M_1 and there is not N/C interlocking.

Sequence Control
Unit 11

Answers to Written Test

1. a. Contacts of a switching device in addition to the main circuit contacts; auxiliary contacts operate with the movement of the main contacts; can be N/O or N/C
   b. Unintentional contact of two or more electrical phases; results in a short circuit
   c. Coming after; following other devices or events
   d. Interrelating with other controllers; a device is connected in such a way that the operation of one part controls the operation of another

2. To assure that one motor is running before any other can operate

3. a. Assures proper order of start-up
   b. Shuts down all "down-stream" motors when a starter fails due to overload

4. a. Main or subassembly line conveyors
   b. Auxiliary equipment associated with machines

5. To prevent two machines or starters from conflicting with one another

6. a. Prevents motor starters from being energized when not desired
   b. Allows another method of sequencing motor starters

7. a. Reversing starters
   b. Machine tools

Sequence Control
Unit 11

Written Test

Name ____________________ Score __________

1. Define the following terms related to sequence control.

   a. Auxiliary contacts — ____________________

   b. Cross phasing — ____________________

   c. Down stream — ____________________

   d. Interlocking — ____________________

2. State the purpose of sequence control.

3. List two advantages of sequence control.

   a. ____________________

   b. ____________________

Written Test

4. List two uses of sequence control.

   a. ______________________________

   b. ______________________________

5. State the purpose of auxiliary contact interlocking.

   ____

   ____

   ____

   ____

6. List two advantages of auxiliary contact interlocking.

   a. ______________________________

   b. ______________________________

7. List two uses of auxiliary contact interlocking.

   a. ______________________________

   b. ______________________________

*Permission to duplicate this test is granted.

Sequence Control
Unit 11

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Assignment Sheet 1—Answer Questions Related to a Sequence Control Diagram Rating _____

Comments: ______________________________

____

Assignment Sheet 2—Answer Questions Related to an Auxiliary Contact Interlocking Diagram Rating _____

Comments: ______________________________

____

Job Sheet 1—Wire Two Starters in Sequence Rating _____

Comments: ______________________________

____

Job Sheet 2—Wire Two Starters with Auxiliary Contact Interlocking Rating _____

Comments: ______________________________

____

Written Test Scores

Pretest _____ Posttest _____ Other _____

Other ______________________________

____

Teacher Signature ______________________________ Date __________

Student Signature ______________________________ Date __________

*Permission to duplicate this form is granted.

Sequence Control
Unit 11

Information Sheet

1. **Terms and definitions**

   a. **Auxiliary contacts** — Contacts of a switching device in addition to the main circuit contacts; auxiliary contacts operate with the movement of the main contacts; can be N/O or N/C

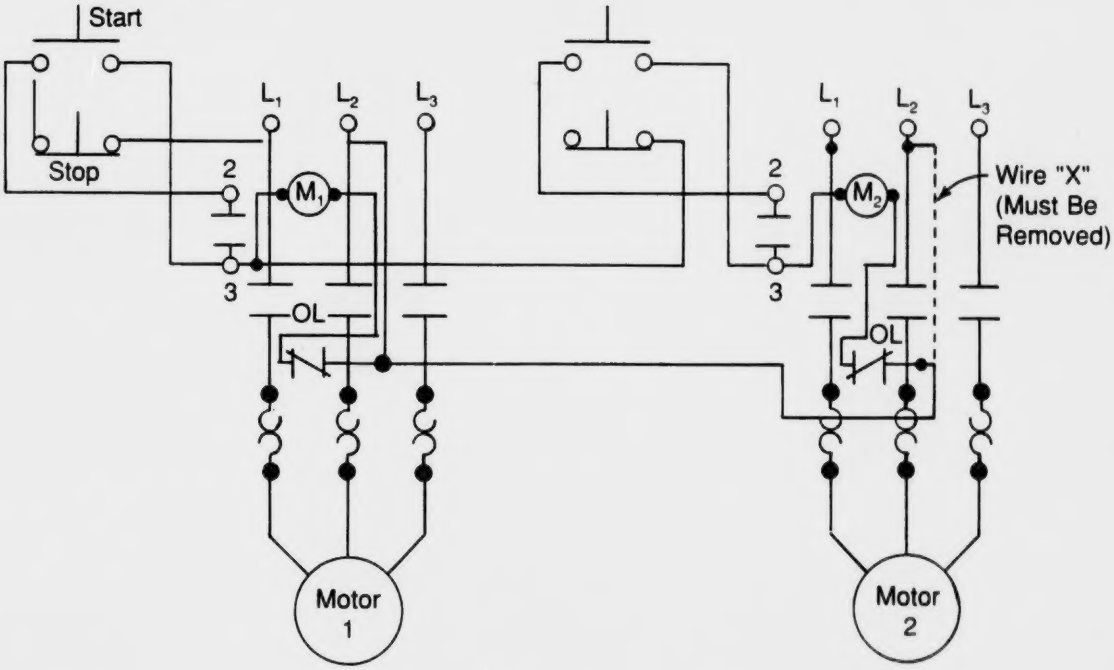
   Note: In most cases, the addition of auxiliary contacts is a simple stack-on and screw-down procedure.

   b. **Cross phasing** — Unintentional contact of two or more electrical phases; results in a short circuit

   c. **Down stream** — Coming after; following other devices or events

   d. **Interlocking** — Interrelating with other controllers; a device is connected in such a way that the operation of one part controls the operation of another

2. **Purpose of sequence control** — To assure that one motor is running before any other can operate



Information Sheet

Note: The wiring diagram indicates all control circuitry originating from starter one. Remember, starters are pre-wired from L_2 through the overloads to the coil. Wire "X" must be removed in order to avoid the possibility of *cross phasing*. Refer to *NEC* Article: 430-72.

3. **Advantages of sequence control**

   a. Assures proper order of start-up

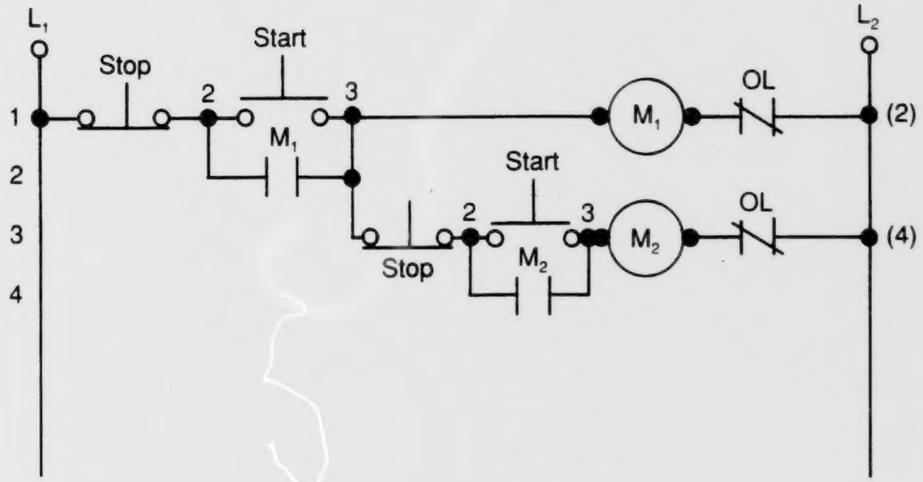
   b. Shuts down all "down-stream" motors when a starter fails due to overload

4. **Uses of sequence control**

   a. Main or subassembly line conveyors

   b. Auxiliary equipment associated with machines

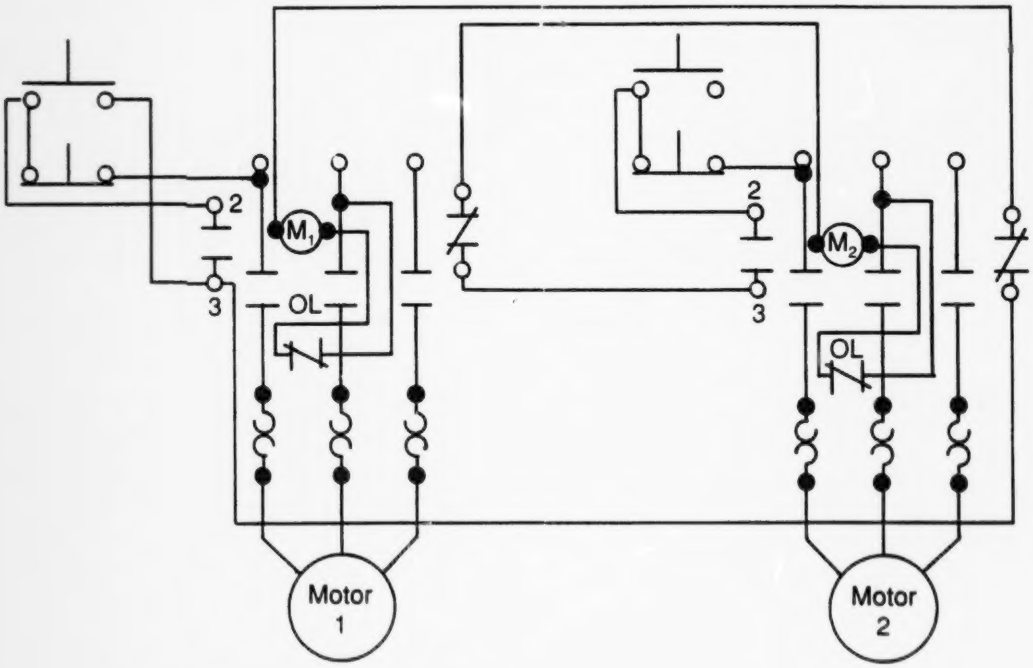
   Examples: High pressure lubricating pumps and hydraulic pumps



Note: Tracing out the ladder diagram, you will note that the first starter is wired in the normal configuration of a three-wire control. Then on rung three you will see the second starter's control circuiting originates from terminal three on the first starter's auxiliary contacts. This allows for control current to flow to the second starter only after starter one seals in. If the OL of starter one opens, both motors will stop, because coil M_1 will de-energize, opening the contacts on rung two.

Information Sheet

5. **Purpose of auxiliary contact interlocking** — To prevent two machines or starters from conflicting with one another



6. **Advantages of auxiliary contact interlocking**

   a. Prevents motor starters from being energized when not desired

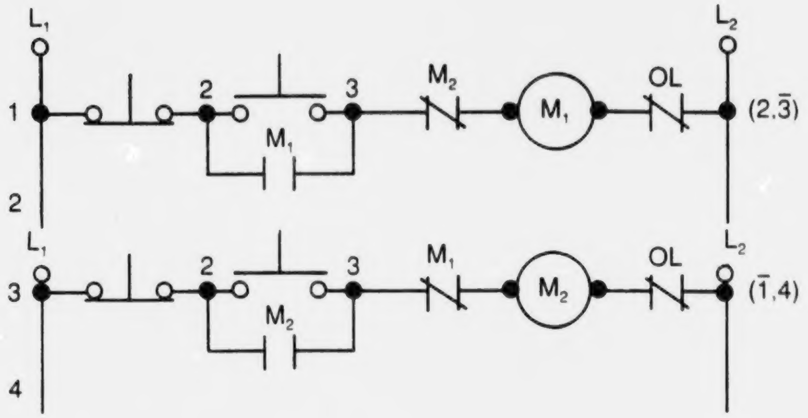
   b. Allows another method of sequencing motor starters

Information Sheet

7. **Uses of auxiliary contact interlocking**

   a. Reversing starters

   b. Machine tools


L₁
L₂
1
2
3
M₂
M₁
OL
(2,3̄)
M₁
2
L₁
L₂
3
2
3
M₁
M₂
OL
(1̄,4)
M₂
4

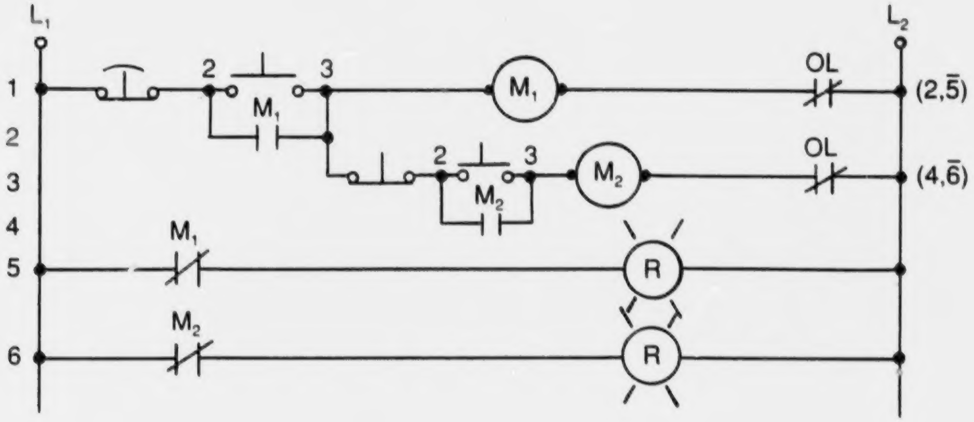
Sequence Control
Unit 11

Assignment Sheet 1—Answer Questions Related to a Sequence Control Diagram

Name ______________________ Overall Rating __________

Evaluation Criteria	**Rating**
Correct answers given	_____
Answers written legibly	_____
Correct explanation of answers given	_____

Directions: Answer the following questions related to the sequence control diagram shown below. The above criteria will be used to evaluate your performance.



A. When the start button on Rung 1 is pressed, what is the sequence of events?

____

____

____

____

Assignment Sheet 1

B. When the start button on Rung 3 is pressed, what is the sequence of events when M_1 is not energized?

C. If both coils M_1 and M_2 are energized, what is the sequence of events if the stop button on Rung 3 is pressed?

D. If both coils M_1 and M_2 are energized, what is the sequence of events if the stop button on Rung 1 is pressed?

E. Is it possible to energize coil M_2 if coil M_1 is not energized? Explain your answer.

Sequence Control
Unit 11

Assignment Sheet 2—Answer Questions Related to an Auxiliary Contact Interlocking Diagram

Name ______________________ Overall Rating __________

Evaluation Criteria	**Rating**
Correct answers given	_____
Answers written legibly	_____
Correct explanation of answers given	_____

Directions: Answer the following questions related to the auxiliary contact interlocking diagram shown on the following page. The above criteria will be used to evaluate your performance.

A. List in order the sequence of events when the start button on Rung 10 is pressed.

____

____

____

B. If no coils are energized, what pilot lights are "on" and what is their purpose?

____

____

____

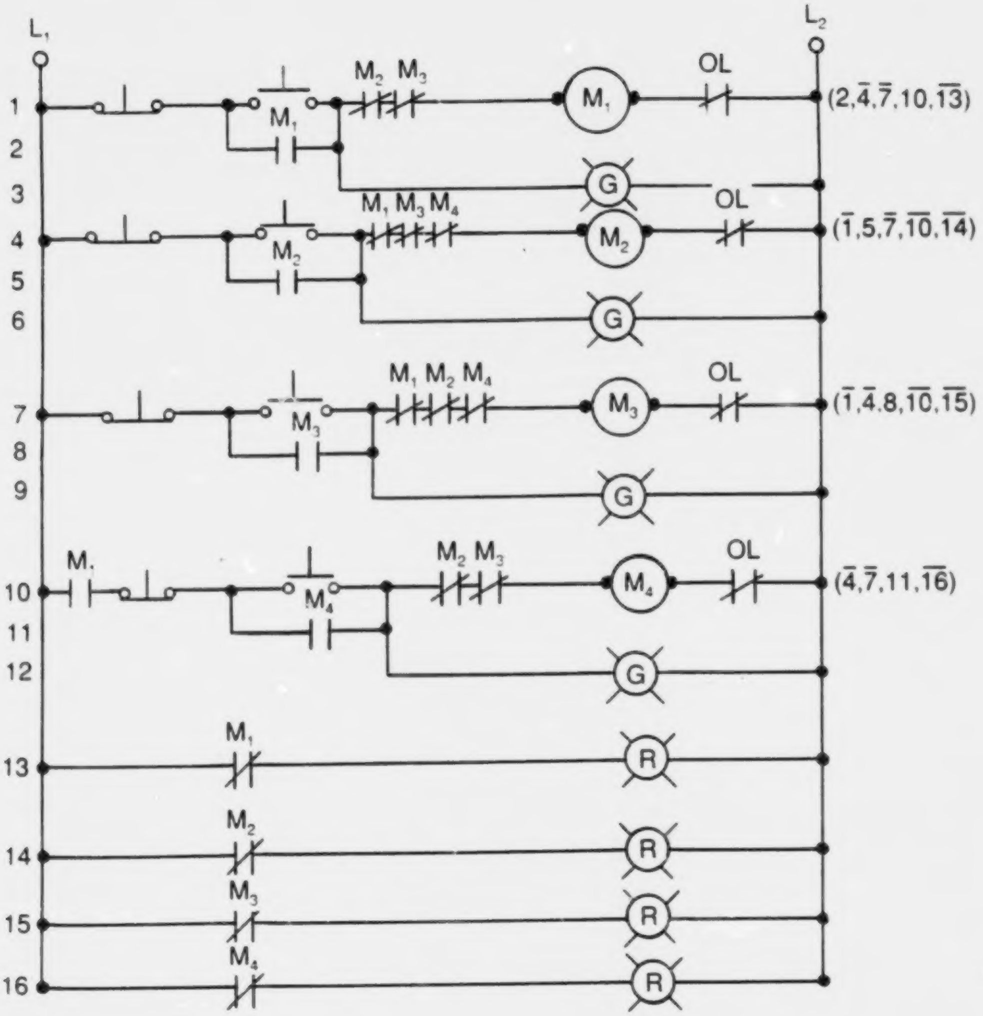
C. Is it possible to energize coil M_4 and coil M_1 at the same time? Explain your answer.

____

____

____

Assignment Sheet 2


L₁
L₂
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
M₁
M₂ M₃
OL
(2,4̄,7̄,10,1̄3̄)
G
M₂
M₁ M₃ M₄
OL
(1̄,5,7̄,1̄0̄,1̄4̄)
G
M₃
M₁ M₂ M₄
OL
(1̄,4̄,8,1̄0̄,1̄5̄)
G
M₁
M₄
M₂ M₃
OL
(4̄,7̄,11,1̄6̄)
G
M₁
R
M₂
R
M₃
R
M₄
R

Sequence Control
Unit 11

Job Sheet 1—Wire Two Starters in Sequence

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Ladder diagram correct	______
Explanation correct	______
System operates	______
Demonstrated good workmanship	______
Complied to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Two three-phase starters
Two start/stop stations
Twelve #10 x 1″ sheet metal screws
15 feet #16 TFFN
Mounting board

B. Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a ladder diagram of a system to operate two starters in sequence. Starter 1 must be energized before starter 2 is able to run.

Job Sheet 1

☐ 4. Have your instructor approve your diagram.

☐ 5. In complete sentences, explain how your system operates.

____

____

____

____

____

____

____

____

☐ 6. Have your instructor approve your explanation.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate the job.

Job Sheet 1

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's Comments: ____

____

____

Sequence Control
Unit 11

Job Sheet 2—Wire Two Starters with Auxiliary Contact Interlocking

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Ladder diagram correct	______
Explanation correct	______
System operates	______
Demonstrated good workmanship	______
Complied to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Two three-phase starters (with N/C auxiliary contacts)
Two start/stop stations
Twelve #10 x 1" sheet metal screws
15 feet #16 THHN
Mounting board
Two pilot lights

B. Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a ladder diagram of a system designed to prevent two starters from being energized simultaneously. The starters must also indicate their energized status through the use of pilot lights.

Job Sheet 2

☐ 4. Have your instructor approve your drawing.

☐ 5. In complete sentences, explain how your system operates.

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____

____

☐ 6. Have your instructor approve your explanation.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate the job.

Job Sheet 2

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Jogging Controls
Unit 12

Objective Sheet

Unit Objective

After completing this unit, the student should be able to read and interpret ladder diagrams dealing with jogging controls as well as wire these types of circuits. The student should demonstrate these competencies by completing the assignment sheets and job sheets, and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Define the term jogging.
2. Identify methods of jogging control.
3. Match methods of jogging control with their advantages.
4. Describe the sequence of operation of ladder diagrams.
5. Convert ladder diagrams to wiring diagrams. (Assignment Sheet 1)
6. Determine the number of conductors needed to operate jogging controls. (Assignment Sheet 2)
7. Wire a jog through a lock-stop push button. (Job Sheet 1)
8. Wire a jog through a two-position selector switch. (Job Sheet 2)
9. Wire a jog through a two-circuit push button. (Job Sheet 3)
10. Wire a jog through a control relay. (Job Sheet 4)

Jogging Controls
Unit 12

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan for students with special needs.
4. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.
5. Develop teaching plan. Adjust for different learning styles.
6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.
8. Discuss unit and specific objectives.
9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
10. Discuss the assignment and job sheets. Review criteria for evaluation of these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.
12. Make copies of the written test. Add or modify test items as needed.
13. Give written test.
14. Record assignment sheet ratings, job sheet ratings, and written test scores on the Unit Evaluation Form. Add any additional assignments or supplemental activities that should be part of the unit evaluation.
15. Reteach and retest as required.

Suggested Activities

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Visit a local industry and view jogging controls in use. Discuss in class what was learned during the visit. Skill areas: **listening** and **oral communication**.
2. Visit a school machine shop and view jogging controls on lathes. Have students write a brief description of their observations. Skill area: **writing**.

Resources Used in Developing This Unit

1. Alerich, Walter N. *Electric Motor Control*, 4th Ed. Albany, NY: Delmar Publishers, Inc., 1988.
2. Kaltwasser, Stan and Gary Flowers. *Commercial and Industrial Wiring*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1988.
3. *National Electrical Code 1993*. Quincy, MA: National Fire Protection Association, 1992.

Suggested Supplemental Resources

1. Croft, Terrell and Wilford I. Summers. *American Electrician's Handbook*, 11th Ed. New York: McGraw-Hill Book Company, 1987.
2. Earley, Mark W., John M. Caloggero and Richard H. Murray. *NEC Handbook 1993*. Quincy, MA: National Fire Protection Association, 1992.
3. O'Riley, Ronald P. *Illustrated Changes in the 1993 National Electrical Code*. Albany, NY: Delmar Publishers, Inc., 1993.
4. *Square D Digest*. Palatine, IL: Square D Company.

Suggested Activities

Instructions for Evaluating Student Performance

Assignment Sheets—Be sure the student understands the criteria on which the evaluation is based. Assign a point value to each criterion and convert the total points to a percentage for grading.

Job Sheets—Be sure the student understands the criteria on which the evaluation is based. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher edition or student manual. Then observe the student performing the procedure. Rate both process and product.

> Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.
>
> Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. Complete the rating by assigning a point value to each criterion and by converting the point total to a percentage for grading. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) which best fits your program needs.

Option A

4 - Skilled—Can perform job with no additional training.
3 - Moderately skilled—Has performed job during training program; limited additional training may be required.
2 - Limited skill—Has performed job during training program; additional training is required to develop skill.
1 - Unskilled—Is familiar with process, but is unable to perform job.

Option B

Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

Jogging Controls
Unit 12

Answers to Assignment Sheets

Assignment Sheet 1 — Diagrams may vary, but all should contain the complete information depicted in the ladder diagram and be workable.

Assignment Sheet 2

A. Conduit 1—3 conductors; #10 AWG
Conduit 2—4 conductors; #14 AWG
Conduit 3—4 conductors; #14 AWG
Conduit 3—3 conductors; #10 AWG
Conduit 4—3 conductors; #10 AWG
Dual element fuse—30 amp
Heater — Answer dependent upon selection charts used

B. Conduit 1—3 conductors; #16 AWG
Conduit 2—3 conductors; #12 AWG
Dual element fuse—15 amp
Heater — Answer dependent upon selection charts used

Jogging Controls
Unit 12

Answers to Written Test

1. The quickly repeated closure of a circuit to start a motor from rest for the purpose of accomplishing small movements

2. a. Control relay
   b. Lock-stop push button
   c. Two-position selector switch
   d. Two-circuit push button

3. a. 4
   b. 1, 2
   c. 3

4. Description should include:

   a. When switch is closed, it reacts as a normal three-wire control. When switch is open, seal in circuit is open.
   b. When jog is pressed, seal in circuit is opened and coil is energized through N/O portion of two-position push button.
   c. When start button is pressed, coil CR energizes, contact CR on Rung 2 closes, and contact CR on Rung 4 closes energizing coil M. When coil M energizes contact M, Rung 2 closes sealing in CR and M. When jog is pressed, coil M energizes; when jog is released coil M de-energizes.

Jogging Controls
Unit 12

Written Test

Name ______________________ Score ____________

1. Define the term jogging.

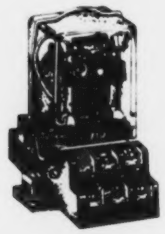
____

____

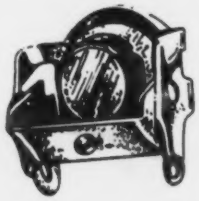
____

____

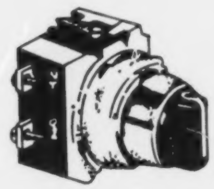
2. Identify the methods of jogging control shown below.



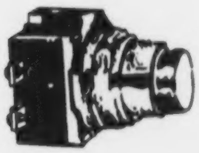
a. ______________________



b. ______________________



c. ______________________



d. ______________________

Written Test

3. Match the methods of jogging control on the right with their correct advantages.

Note: There may be more than one correct answer.

______a. Extremely reliable; may be used on multiple starters

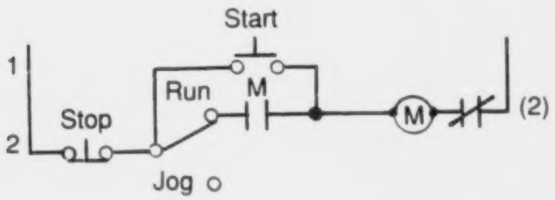
______b. Inexpensive; easy to install or retrofit; reliable

______c. Easy to operate; easy to install on initial wiring

1. Two position selector switch
2. Lock-stop push button
3. Two circuit push button
4. Control relay

4. Describe the sequence of operation of the three following ladder diagrams.

a.



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____

____

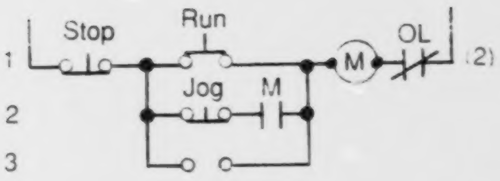
____

____

____

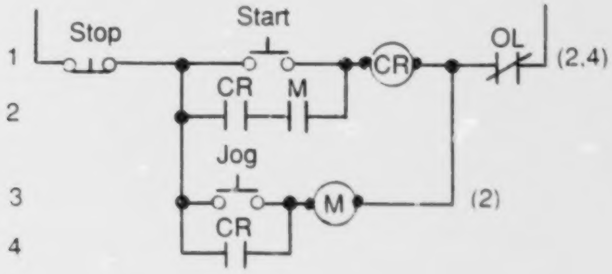
Written Test

b.



Stop
Run
OL
1
M
(2)
Jog
M
2
3

c.



Start
Stop
OL
1
CR
(2,4)
CR
M
2
Jog
3
M
(2)
CR
4

*Permission to duplicate this test is granted.

Jogging Controls
Unit 12

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Assignment Sheet 1—Convert Ladder Diagrams to Wiring Diagrams Rating _____

Comments: ____

____

Assignment Sheet 2—Determine the Number of Conductors Needed to Operate Jogging Controls Rating _____

Comments: ____

____

Job Sheet 1—Wire a Jog Through a Lock-Stop Push Button Rating _____

Comments: ____

____

Job Sheet 2—Wire a Jog Through a Two-Position Selector Switch Rating _____

Comments: ____

____

Job Sheet 3—Wire a Jog Through a Two-Circuit Push Button Rating _____

Comments: ____

____

Job Sheet 4—Wire a Jog Through a Control Relay Rating _____

Comments: ____

____

Written Test Scores

Pretest _____ Posttest _____ Other _____

Other ____

____

Teacher Signature ______________ ______________ Date __________

Student Signature ______________ ______________ Date __________

***Permission to duplicate this form is granted.**

Jogging Controls
Unit 12

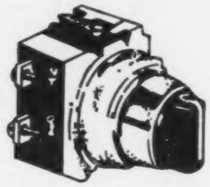
Information Sheet

1. **Jogging** — The quickly repeated closure of a circuit to start a motor from rest for the purpose of accomplishing small movements

   Example: Short movement of a turret lathe in order to load material into the chuck

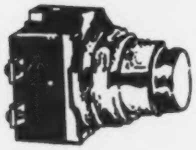
2. **Methods of jogging control**

   a. Two-position selector switch



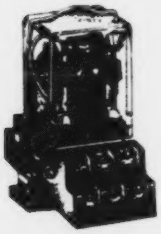
   b. Lock-stop push button

   c. Two-circuit push button



Note: This is a momentary push button with a two-circuit NC/NO contact block.

d. Control relay



3. **Advantages of jogging control methods**

a. Two position selector switch

- Inexpensive
- Easy to install or retrofit
- Reliable

b. Lock-stop push button

- Inexpensive
- Easy to install or retrofit
- Reliable

c. Two circuit push button

- Easy to operate
- Easy to install on initial wiring

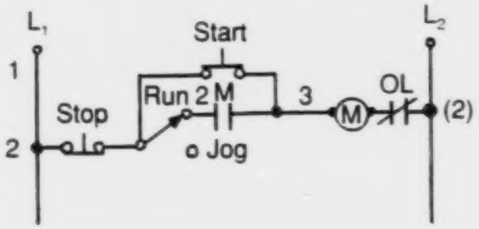
d. Control relay

- Extremely reliable
- May be used on multiple starters

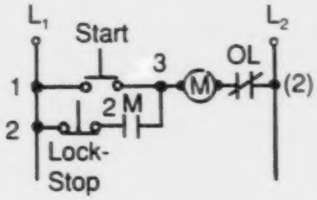
Information Sheet

4. **Sequence of operations**

   a. Two-position selector switch — When switch is in the run position the circuit operates as a normal three-wire control. When switch is in the jog position the memory circuit will no longer operate, thus allowing the start button to "change" to a jog button.


L₁
Start
L₂
1
Run
2M
3
OL
Stop
(2)
2
Jog

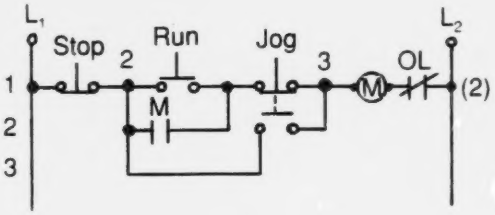
   b. Lock-stop push button — When the lock-stop is in the closed position, the circuit operates as a normal three-wire control. When the lock-stop is locked open, it allows the start button to function as a jog, due to the open memory circuit.


L₁
Start
L₂
3
OL
1
M
(2)
2M
2
Lock-
Stop

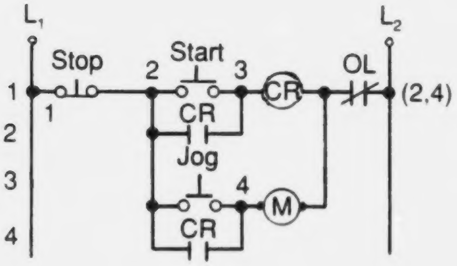
Information Sheet

c. Two-circuit push button — The normally closed contacts of the two-circuit push button are in series with the memory contacts. The normally open contacts are used to energize the coil. When the jog button is pressed, the seal-in circuit is opened and the coil is energized. When the button is released, the coil is de-energized before the seal-in portion of the circuit closes again.

Caution: A control station using this circuit may maintain the circuit when the operator's finger is removed too quickly from the button. This could injure production workers, equipment, and machinery. Such a circuit is not recommended.



d. Control relay — The control relay is used to seal in the circuit. When the start button is depressed, the coil CR (control relay) is energized. When CR energizes, N/O contacts CR on rung 2 and 4 close. CR rung 4 acts as seal-in for the starter's coil.



Jogging Controls
Unit 12

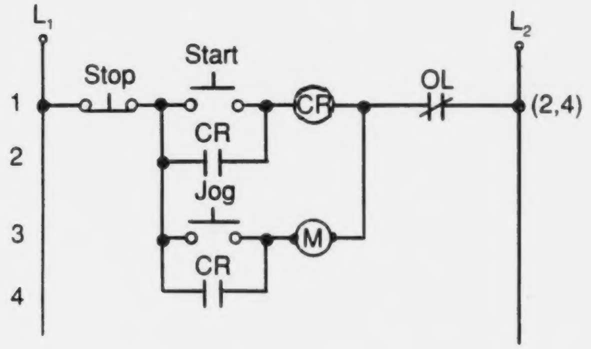
Assignment Sheet 1—Convert Ladder Diagrams to Wiring Diagrams

Name ______________________ Overall Rating __________

Evaluation Criteria	Rating
Completeness of diagrams	_____
Systems will work as drawn	_____
Labels and connections legible	_____

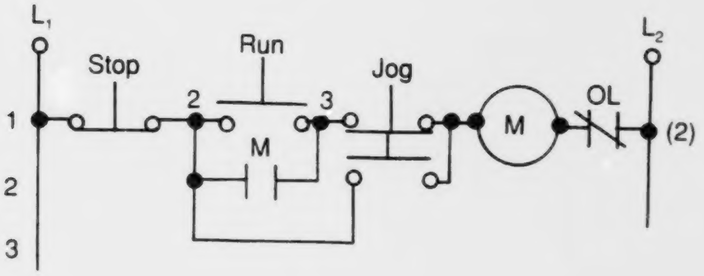
Directions: Convert the ladder diagrams shown below to wiring diagrams. The above criteria will be used to evaluate your performance.

A.

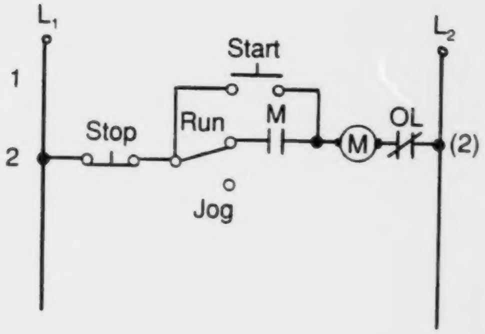


Assignment Sheet 1

B.


L₁
Stop
Run
Jog
L₂
1
2
3
2
3
M
M
OL
(2)

C.


L₁
L₂
Start
1
2
Stop
Run
M
M
OL
(2)
Jog

Jogging Controls
Unit 12

Assignment Sheet 2—Determine the Number of Conductors Needed to Operate Jogging Controls

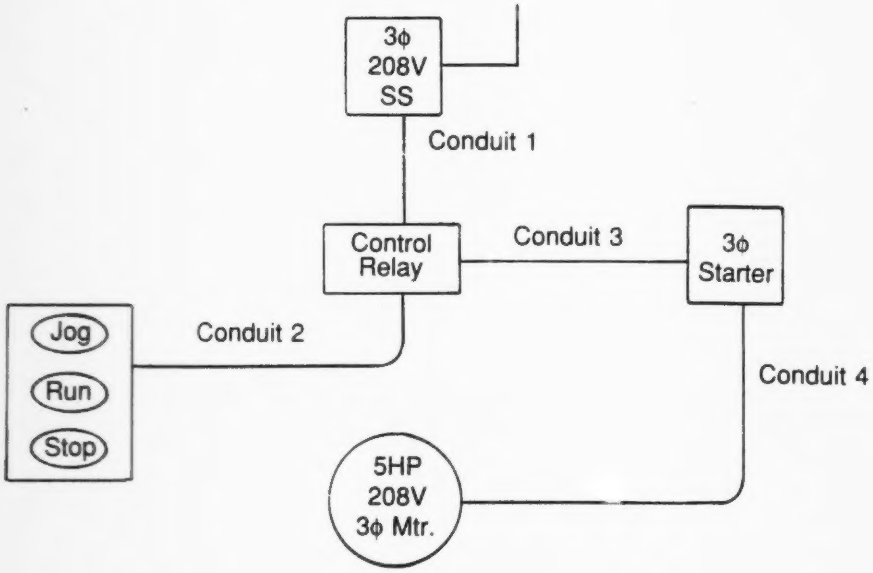
Name ______________________________ Overall Rating __________

Evaluation Criteria	**Rating**
Correct answers given	______
Demonstrated ability to use *NEC* and other resource materials	______

Directions: Using the *NEC* and other materials provided by instructor, determine the size and number of conductors needed to operate the following jogging control circuits. You must also determine the proper fuse size using a dual element time delay fuse, and the proper heater size. The above criteria will be used to evaluate your performance.

Note: This starter has a line voltage coil.

A.



3ϕ
208V
SS
Conduit 1
Control Relay
Conduit 3
3ϕ Starter
Jog
Run
Stop
Conduit 2
Conduit 4
5HP
208V
3ϕ Mtr.

Assignment Sheet 2

Conduit 1—____________ conductors; ____________ AWG

Conduit 2—____________ conductors; ____________ AWG

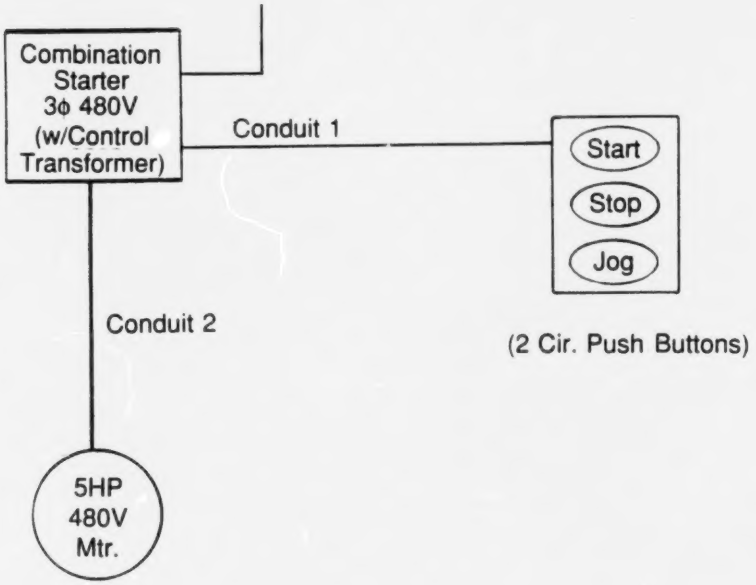
Conduit 3—____________ conductors; ____________ AWG

Conduit 4—____________ conductors; ____________ AWG

Dual element fuse—____________ amps

Heater —____________

B.


Combination Starter 3ϕ 480V (w/Control Transformer)
Conduit 1
Start
Stop
Jog
(2 Cir. Push Buttons)
Conduit 2
5HP 480V Mtr.

Conduit 1—____________ conductors; ____________ AWG

Conduit 2—____________ conductors; ____________ AWG

Fuse size—____________ (dual element time delay)

Heater amps—____________; part number ____________

Jogging Controls
Unit 12

Job Sheet 1—Wire a Jog Through a Lock-Stop Push Button

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Ladder diagram correct	______
Sequence description correct	______
Proper operation	______
Demonstrated good workmanship	______
Complied to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
Three-phase starter
Three-element control station
Normally open push button
Two normally closed push buttons
Lock-stop device
Eight #10 × 1″ sheet metal screws
15 feet of #14 THHN

B. Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

Job Sheet 1

☐ 3. Draw a ladder diagram of a jogging control using a lock-stop push button.

☐ 4. Have your instructor approve your diagram.

☐ 5. In complete sentences, describe the sequence of operation of your system.

____

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____

____

____

☐ 6. Have your instructor approve your system description.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate your job.

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's comments: ____

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____

Jogging Controls
Unit 12

Job Sheet 2—Wire a Jog Through a Two-Position Selector

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	____
Ladder diagram correct	____
Sequence description correct	____
Proper operation	____
Demonstrated good workmanship	____
Complied to *NEC*	____

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
Three-phase starter
Three-element control station
N/O push button
N/C push button
N/O two-position selector switch
Eight #10 × 1″ sheet metal screws
15 feet of #14 THHN

B. Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

Job Sheet 2

☐ 3. Draw a ladder diagram of a jogging control system using a two-position selector switch.

☐ 4. Have your instructor approve your diagram.

☐ 5. In complete sentences, describe the sequence of operation of your system.

____

____

____

____

____

____

____

____

☐ 6. Have your instructor approve your system description.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate your job.

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's comments: ____

____

____

Jogging Controls
Unit 12

Job Sheet 3—Wire a Jog Through a Two-Circuit Push Button

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Ladder diagram correct	______
Sequence description correct	______
Proper operation	______
Demonstrated good workmanship	______
Complied to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
Three-phase starter
Three-element control station
N/O push button
N/C push button
N/O-N/C two-circuit push button
Eight #10 × 1" sheet metal screws
15 feet of #14 THHN

B. Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

Job Sheet 3

☐ 3. Draw a ladder diagram of a jogging control system using a two-circuit push button.

☐ 4. Have your instructor approve your diagram.

☐ 5. In complete sentences, describe the sequence of operation of your system.

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☐ 6. Have your instructor approve your system description.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate your job.

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's comments: ________________________________

____

____

Jogging Controls
Unit 12

Job Sheet 4—Wire a Jog Through a Control Relay

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	_____
Ladder diagram correct	_____
Sequence description correct	_____
Proper operation	_____
Demonstrated good workmanship	_____
Complied to *NEC*	_____

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
Three-phase starter
Three-element control station
Two N/O push buttons
N/C push button
Two pole control relay with compatible coil voltage
Eight #10 × 1″ sheet metal screws
15 feet of #14 THHN

B. Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

Job Sheet 4

☐ 3. Draw a ladder diagram of a jogging control system using a control relay.

☐ 4. Have your instructor approve your diagram.

☐ 5. In complete sentences, describe the sequence of operation of your system.

____

____

____

____

____

____

____

____

☐ 6. Have your instructor approve your system description.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate your job.

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's comments: ____

____

____

Reversing Starters
Unit 13

Objective Sheet

Unit Objective

After completing this unit, the student should be able to wire a reversing starter under various conditions. The student should demonstrate these competencies by completing the assignment sheets and job sheets, and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to reversing starters with their correct definitions.
2. Identify types of reversing starter construction.
3. List types of interlocking methods for reversing starters.
4. Identify types of drum controls.
5. Complete a drum switch diagram.
6. Describe the sequence of operation of ladder diagrams. (Assignment Sheet 1)
7. Determine the number of conductors needed to operate a reversing control. (Assignment Sheet 2)
8. Wire a reversing starter with a three-position selector switch. (Job Sheet 1)
9. Wire a reversing starter with one control station using auxiliary contact and mechanical interlock. (Job Sheet 2)
10. Wire a reversing starter with one control station using push button interlock and auxiliary contact interlock. (Job Sheet 3)
11. Wire a reversing starter with two control stations. (Job Sheet 4)
12. Wire drum switches. (Job Sheet 5)
13. Wire a reversing starter with jog in both directions. (Job Sheet 6)

Reversing Starters
Unit 13

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan for students with special needs.
4. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.
5. Develop teaching plan. Adjust for different learning styles.
6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.
8. Discuss unit and specific objectives.
9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
10. Discuss the assignment and job sheets. Review criteria for evaluation of these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.
12. Make copies of the written test. Add or modify test items as needed.
13. Give written test.
14. Record assignment sheet ratings, job sheet ratings, and written test scores on the Unit Evaluation Form. Add any additional assignments or supplemental activities that should be part of the unit evaluation.

Suggested Activities

15. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Disassemble several reversing starters and show the class while describing how mechanical interlocking works. Skill area: **listening**.
2. Arrange a tour of a supply house to view different brands and sizes of reversing starters. Conduct a class discussion of the similarities and differences students observed in the different brands. Skill area: **oral communication**.

Resources Used in Developing This Unit

1. Alerich, Walter N. *Electric Motor Control*, 4th Ed. Albany, NY: Delmar Publishers, Inc., 1988.
2. Kaltwasser, Stan and Gary Flowers. *Commercial and Industrial Wiring*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1988.
3. *National Electrical Code 1993*. Quincy, MA: National Fire Protection Association, 1992.

Suggested Supplemental Resources

1. Croft, Terrell and Wilford I. Summers. *American Electrician's Handbook*, 11th Ed. New York: McGraw-Hill Book Company, 1987.
2. Earley, Mark W., John M. Caloggero and Richard H. Murray. *NEC Handbook 1993*. Quincy, MA: National Fire Protection Association, 1992.
3. O'Riley, Ronald P. *Illustrated Changes in the 1993 National Electrical Code*. Albany, NY: Delmar Publishers, Inc., 1993.

Suggested Activities

Instructions for Evaluating Student Performance

Assignment Sheets—Be sure the student understands the criteria on which the evaluation is based. Assign a point value to each criterion and convert the total points to a percentage for grading.

Job Sheets—Be sure the student understands the criteria on which the evaluation is based. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher edition or student manual. Then observe the student performing the procedure. Rate both process and product.

> Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.
>
> Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. Complete the rating by assigning a point value to each criterion and by converting the point total to a percentage for grading. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) which best fits your program needs.

Option A

4 - Skilled—Can perform job with no additional training.
3 - Moderately skilled—Has performed job during training program; limited additional training may be required.
2 - Limited skill—Has performed job during training program; additional training is required to develop skill.
1 - Unskilled—Is familiar with process, but is unable to perform job.

Option B

Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

Reversing Starters
Unit 13

Answers to Assignment Sheets

Assignment Sheet 1—Exact answers may vary. Look for basic knowledge of the working systems.

Assignment Sheet 2

Conduit 1 — ½ inch; 3; #12

Conduit 2 — ¾ inch; 8; #14

Conduit 3 — ½ inch; 5; #14

Conduit 4 — ¾ inch; 3; #12 & 5, #14

Conduit 5 — ½ inch; 3; #12

Reversing Starters
Unit 13

Answers to Written Test

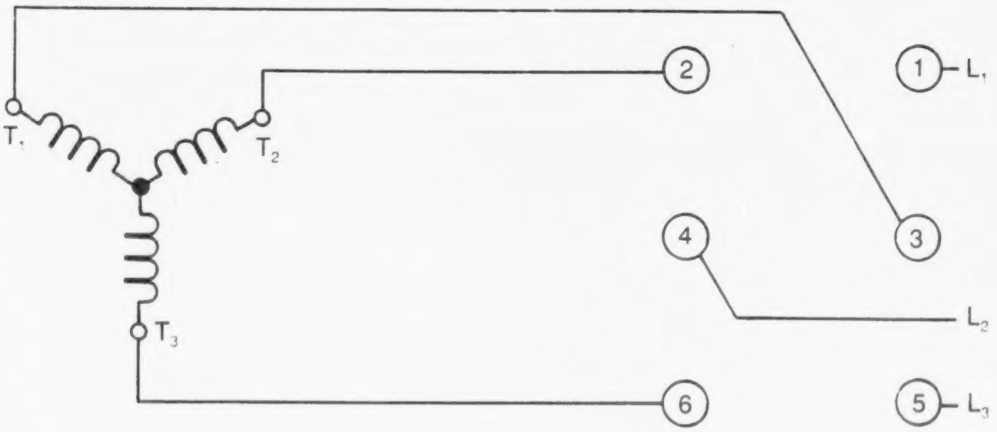
1. a. 2
   b. 1
   c. 3
   d. 5
   e. 4

2. a. Horizontal construction
   b. Vertical construction

3. a. Push-button interlocking
   b. Auxiliary contact interlocking
   c. Mechanical interlocking

4. a. Flush mount knob operator
   b. Flush mount adjustable operator
   c. Surface mounting standard lever

5.



Reversing Starters
Unit 13

Written Test

Name ______________________________ Score ______________

1. Match the terms on the right with their correct definitions.

_______a. Means of locking out contactors through the use of mechanical devices such as cams or blocks

_______b. A switch having electrical connecting parts in the form of fingers held by spring pressure against contact segments or the surface of a rotating cylinder

_______c. Means of interlocking reversing starters through the use of two-circuit push buttons with normally open and normally closed contacts

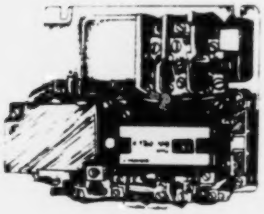
_______d. Starter consisting of two identical contactors and one overload relay assembly; used in reversal of polyphase motors

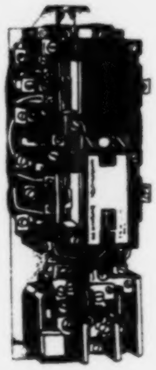
_______e. Condition that occurs when both forward and reversing push buttons are operated simultaneously. Coils "race" to close

1. Drum switch
2. Mechanical interlocking
3. Push-button interlocking
4. Racing
5. Reversing starters

Written Test

2. Identify the two types of reversing starter constructions shown below.





a. ______________________ b. ______________________

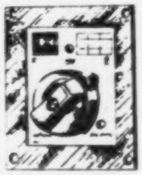
3. List three types of interlocking methods for reversing starters.

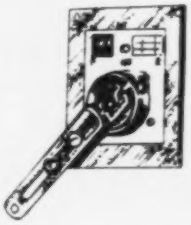
a. ______________________

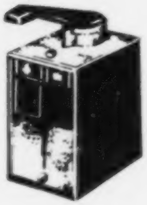
b. ______________________

c. ______________________

4. Identify the three types of drum switches shown below.



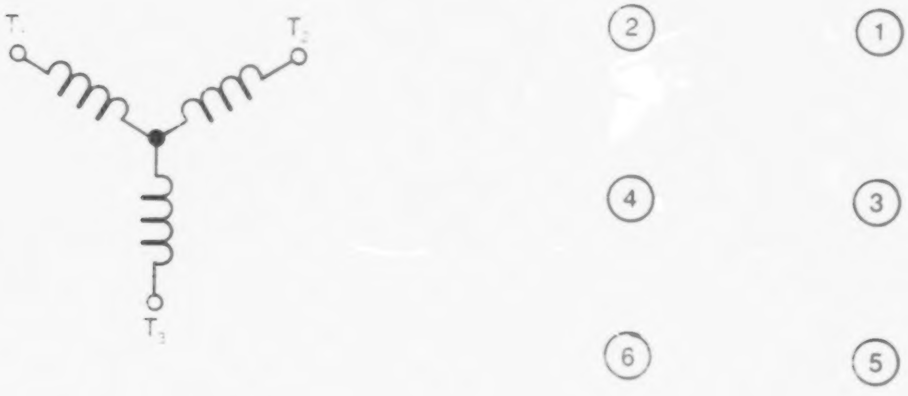




a. ______________ b. ______________ c. ______________

Written Test

5. Complete the following drum switch diagram.



*Permission to duplicate this test is granted.

Reversing Starters
Unit 13

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Assignment Sheet 1—Describe the Sequence of Operation of Ladder Diagrams Rating ______

Comments: ____

____

Assignment Sheet 2—Determine the Number of Conductors Needed to Operate a Reversing Control Rating ______

Comments: ____

____

Job Sheet 1—Wire a Reversing Starter with a Three-Position Selector Switch Rating ______

Comments: ____

____

Job Sheet 2—Wire a Reversing Starter with One Control Station Using Auxiliary Contact and Mechanical Interlock Rating ______

Comments: ____

____

Job Sheet 3—Wire a Reversing Starter with One Control Station Using Push Button Interlock and Auxiliary Contact Interlock Rating ______

Comments: ____

____

Job Sheet 4—Wire a Reversing Starter with Two Control Stations Rating ______

Comments: ____

____

Job Sheet 5—Wire Drum Switches Rating ______

Comments: ____

____

Unit Evaluation Form

Job Sheet 6—Wire a Reversing Starter with Jog in Both Directions Rating ______

Comments: ____

____

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ____

____

Teacher Signature ______________________________ Date ____________

Student Signature ______________________________ Date ____________

*Permission to duplicate this form is granted.

564

Reversing Starters
Unit 13

Information Sheet

1. **Terms and definitions**

    a. **Drum switch** — A switch having electrical connecting parts in the form of fingers held by spring pressure against contact segments or the surface of a rotating cylinder

    b. **Mechanical interlocking** — Means of locking out contactors through the use of mechanical devices such as cams or blocks

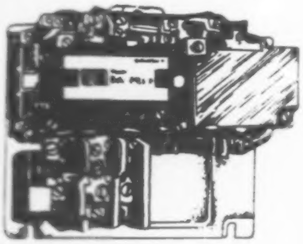
    c. **Push-button interlocking** — Means of interlocking reversing starters through the use of two-circuit push buttons with normally open and normally closed contacts

    d. **Racing** — Condition that occurs when both forward and reversing push buttons are operated simultaneously; coils "race" to close

    e. **Reversing starter** — Starter consisting of two identical contactors and one overload relay assembly; used in reversal of polyphase motors

2. **Types of reversing starter construction**

    a. Horizontal construction

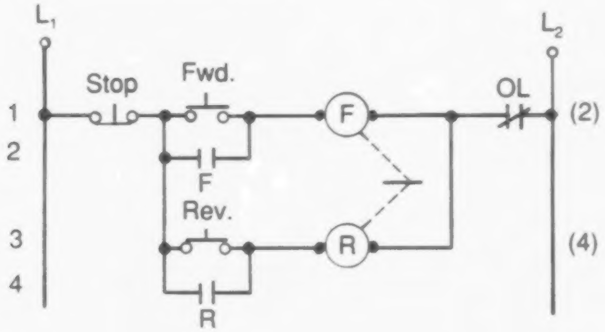


Information Sheet

b. Vertical construction

3. Types of interlocking methods for reversing starters

a. Mechanical interlocking

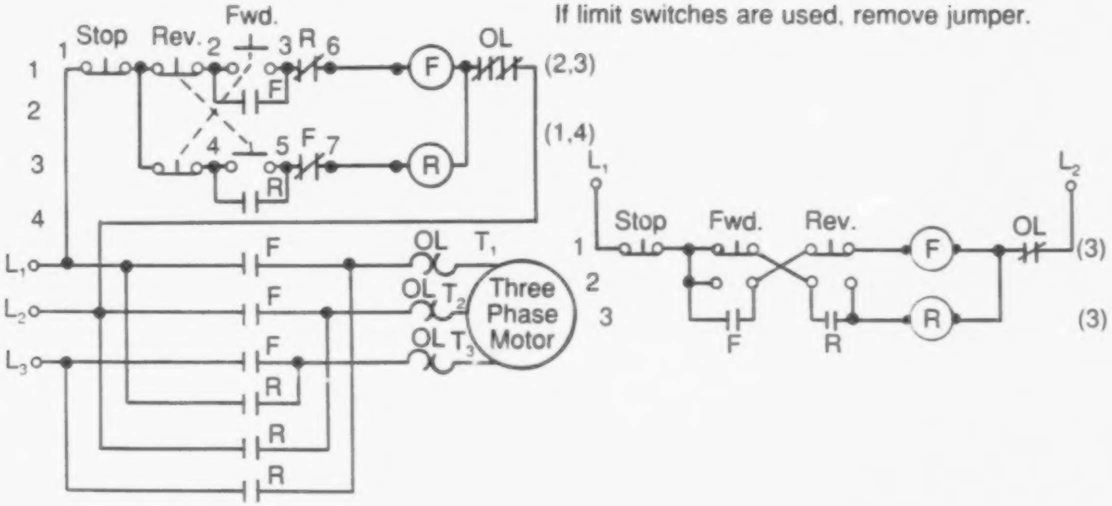


Note: A mechanical interlock is either factory or field installed between the forward and reverse contactors. It locks out one contactor at the beginning of the stroke of either contactor. This prevents short circuits and burnouts.

Information Sheet

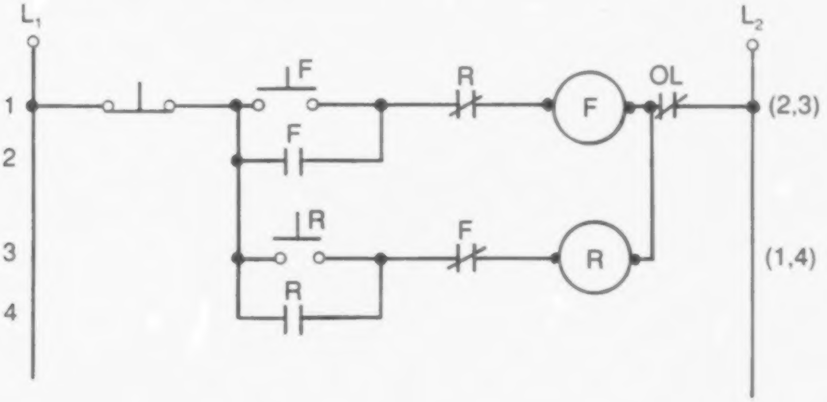
b. Push-button interlocking

If limit switches are used, remove jumper.


Stop
Rev.
Fwd.
1
2
3
4
5
6
7
R
F
OL
(2,3)
(1,4)
L₁
L₂
L₃
T₁
T₂
T₃
Three Phase Motor
Stop
Fwd.
Rev.
OL
(3)
(3)

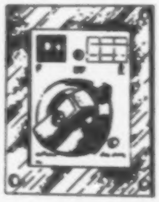
Note: This method will not allow the coils to race.

c. Auxiliary contact interlocking

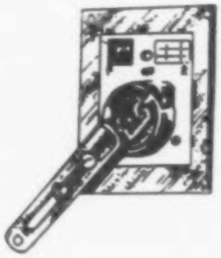

L₁
L₂
1
2
3
4
F
R
OL
(2,3)
(1,4)

4. **Types of drum controls**

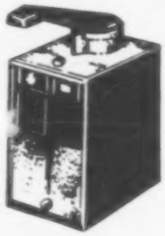
a. Flush mount knob operator



b Flush mount adjustable operator



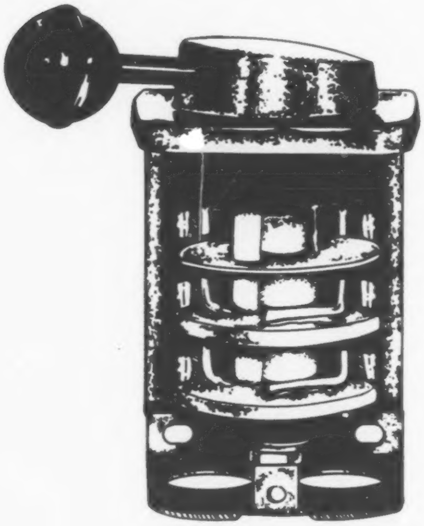
c. Surface mounting standard lever

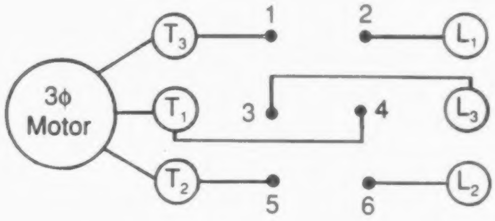


Information Sheet

5. Drum switch diagrams

Note: Drum switches may be used as the only means of controlling a motor. However, if the starting inrush current is higher than the rating of the drum switch, a starter must be used.

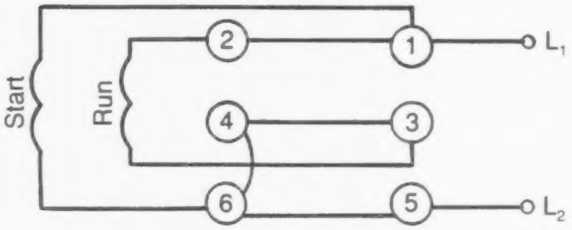



T$_3$
1
2
L$_1$
3φ Motor
T$_1$
3
4
L$_3$
T$_2$
5
6
L$_2$

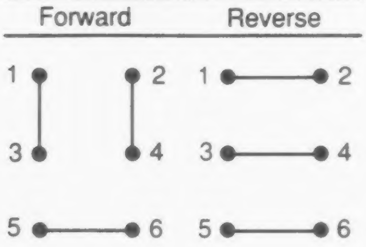
Connections for 3φ

Forward	Reverse
L_1 to T_3 L_2 to T_2 L_3 to T_1	L_1 to T_1 L_2 to T_2 L_3 to T_3

Single Phase


2
1
L$_1$
Start
Run
4
3
6
5
L$_2$

Connections for 1φ


Forward
Reverse
1
2
3
4
5
6
1
2
3
4
5
6

Reversing Starters
Unit 13

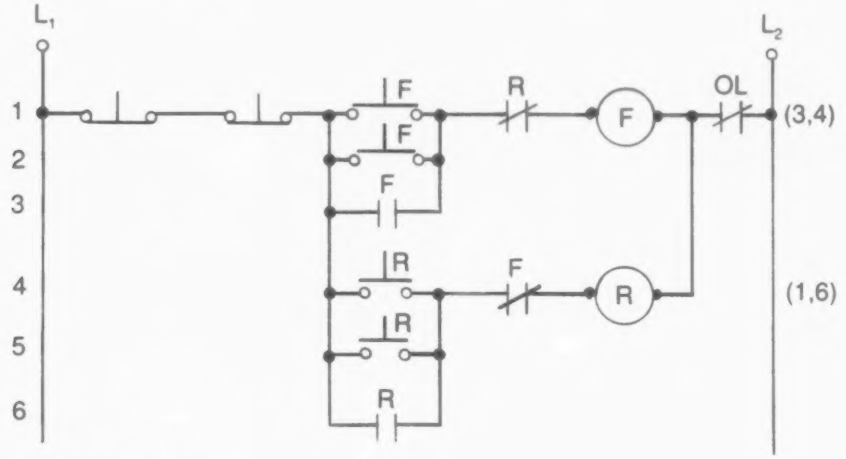
Assignment Sheet 1—Describe the Sequence of Operation of Ladder Diagrams

Name ______________________________ Overall Rating __________

Evaluation Criteria	**Rating**
Correct sequence given for Diagram A	______
Correct sequence given for Diagram B	______
Correct sequence given for Diagram C	______
Legible writing	______

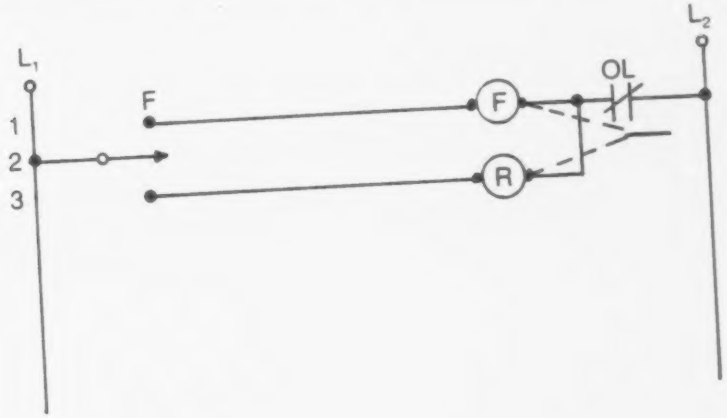
Directions: Describe the sequence of operation of the three ladder diagrams shown below. The above criteria will be used to evaluate your performance.

A.

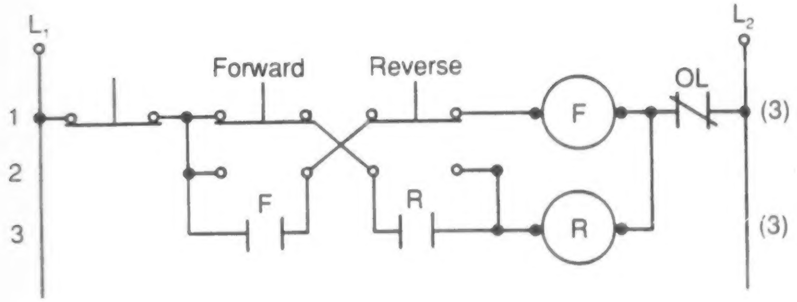


Assignment Sheet 1

B.


L1
L2
F
1
2
3
F
R
OL

Assignment Sheet 1


L₁
L₂
Forward
Reverse
OL
F
R
F
R
1
2
3
(3)
(3)

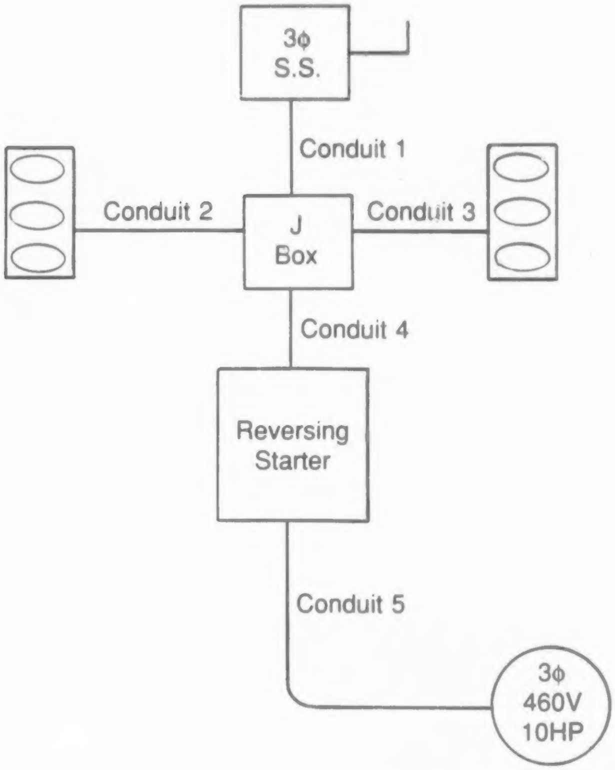
Reversing Starters
Unit 13

Assignment Sheet 2—Determine the Number of Conductors Needed to Operate a Reversing Control

Name ______________________________ Overall Rating __________

Evaluation Criteria	**Rating**
Correct answers given	______
Complied to *NEC*	______

Directions: Determine the number of 14 Awg control conductors needed to operate the control circuit of a system using two control stations with push button and auxiliary contact interlock. Also determine the number and size of motor branch circuit conductors as well as the size of conduit. The above criteria will be used to evaluate your performance.


3ϕ
S.S.
Conduit 1
Conduit 2
J
Box
Conduit 3
Conduit 4
Reversing
Starter
Conduit 5
3ϕ
460V
10HP

Assignment Sheet 2

Conduit 1 — ____________ inch; ____________ conductors; ____________ AWG THW

Conduit 2 — ____________ inch; ____________ conductors; ____________ AWG THW

Conduit 3 — ____________ inch; ____________ conductors; ____________ AWG THW

Conduit 4 — ____________ inch; ____________ conductors; ____________ AWG THW

Conduit 5 — ____________ inch; ____________ conductors; ____________ AWG THW

Reversing Starters
Unit 13

Job Sheet 1—Wire a Reversing Starter with a Three-Position Selector Switch

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Diagram correct	______
Explanation correct	______
System operates	______
Demonstrated good workmanship	______
Complied to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
Three-position selector switch (N/O-N/O) and enclosure
Reversing starter with mechanical interlock
Eight #10 x 1″ sheet metal screws
15 feet of #16 THWN
Mounting board

B. Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a ladder diagram of a control system using a three-position selector switch to operate a reversing starter.

Job Sheet 1

☐ 4. Have your instructor approve your diagram.

☐ 5. In complete sentences, explain how your system operates.

____

____

____

____

____

____

____

____

☐ 6. Have your instructor approve your explanation.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate the job.

Job Sheet 1

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's Comments: ____

____

____

Reversing Starters
Unit 13

Job Sheet 2—Wire a Reversing Starter with One Control Station Using Auxiliary Contact and Mechanical Interlock

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Diagram correct	______
Explanation correct	______
System operates	______
Demonstrated good workmanship	______
Complied to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
Three-element control station
N/C push button
Two N/O push buttons
Reversing starter with mechanical interlock
Eight #10 x 1" sheet metal screws
Mounting board
15 feet of #16 THWN

B. Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

Job Sheet 2

☐ 3. Draw a ladder diagram of a reversing control with one control station, using auxiliary contact and mechanical interlocking.

☐ 4. Have your instructor approve your diagram.

☐ 5. In complete sentences, explain how your system operates.

____

____

____

____

____

____

____

____

☐ 6. Have your instructor approve your explanation.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate the job.

Job Sheet 2

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Reversing Starters
Unit 13

Job Sheet 3—Wire a Reversing Starter with One Control Station Using Push-Button and Auxiliary Contact Interlocking

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Diagram correct	______
Explanation correct	______
System operates	______
Demonstrated good workmanship	______
Complied to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
Three-element control station
N/C push button
Two N/O-N/C two circuit push buttons
Reversing starter
Eight #10 x 1″ sheet metal screws
Mounting board
15 feet of #16 THWN

B. Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check cut proper tools and materials.

Job Sheet 3

☐ 3. Draw a ladder diagram of a system to operate a reversing starter using push button and auxiliary contact interlocking.

☐ 4. Have your instructor approve your diagram.

☐ 5. In complete sentences, explain how your system operates.

____

____

____

____

____

____

____

____

☐ 6. Have your instructor approve your explanation.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate the job.

Job Sheet 3

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's Comments: ____________________

____

____

Reversing Starters
Unit 13

Job Sheet 4—Wire a Reversing Starter with Two Control Stations

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
Practiced safety rules throughout procedure	______
Diagram correct	______
Explanation correct	______
System operates	______
Demonstrated good workmanship	______
Complied to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
Two forward/reverse/stop control stations
Reversing starter
Ten #10 x 1″ sheet metal screws
Mounting board
20 feet of #16 THWN

B. Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a ladder diagram of a reversing control using two control stations.

Job Sheet 4

☐ 4. Have your instructor approve your diagram.

☐ 5. In complete sentences, explain how your system operates.

____

____

____

____

____

____

____

____

☐ 6. Have your instructor approve your explanation.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate the job.

Job Sheet 4

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Reversing Starters
Unit 13

Job Sheet 5—Wire Drum Switches

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Diagrams correct	______
Switches reversed motor rotation	______
Demonstrated good workmanship	______
Complied to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

Part I

A. Tools and materials

Pouch tools
Drum switch for polyphase motors
3ϕ ¾hp. motor
3ϕ voltage source
Two #10 x 1" sheet metal screws
Mounting board

B. Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a wiring diagram of a drum switch.

Note: Terminal connections for polyphase motors are located on the inside of the drum switch cover.

Job Sheet 5

☐ 4. Have your instructor approve your diagram.

☐ 5. Wire the drum switch.

☐ 6. Have your instructor evaluate your job.

☐ 7. Disassemble the system.

☐ 8. Return tools and materials to proper storage.

☐ 9. Clean the work area.

Part II

A. Tools and materials

Pouch tools
Drum switch for 1ϕ motor
1ϕ ¾hp. motor
1ϕ 240V voltage source
Two #10 x 1″ sheet metal screws
Mounting board

B. Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

Job Sheet 5

☐ 3. Draw a wiring diagram of a drum switch.

Note: Terminal connections for single-phase motors are located on the inside of the drum switch cover.

☐ 4. Have your instructor approve your diagram.

☐ 5. Wire the drum switch.

☐ 6. Have your instructor evaluate your job.

☐ 7. Disassemble the system.

☐ 8. Return tools and materials to proper storage.

☐ 9. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Reversing Starters
Unit 13

Job Sheet 6—Wire a Reversing Starter with Jog in Both Directions

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Starter operated correctly	______
Jog operated correctly	______
Demonstrated good workmanship	______
Complied to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
N/C push button
Two N/O push buttons
Two N/O-N/C two-circuit push buttons
Three element control station
Two element control station
Reversing starter
Mounting board
Ten #10 x 1″ sheet metal screws
20 feet of #16 THWN

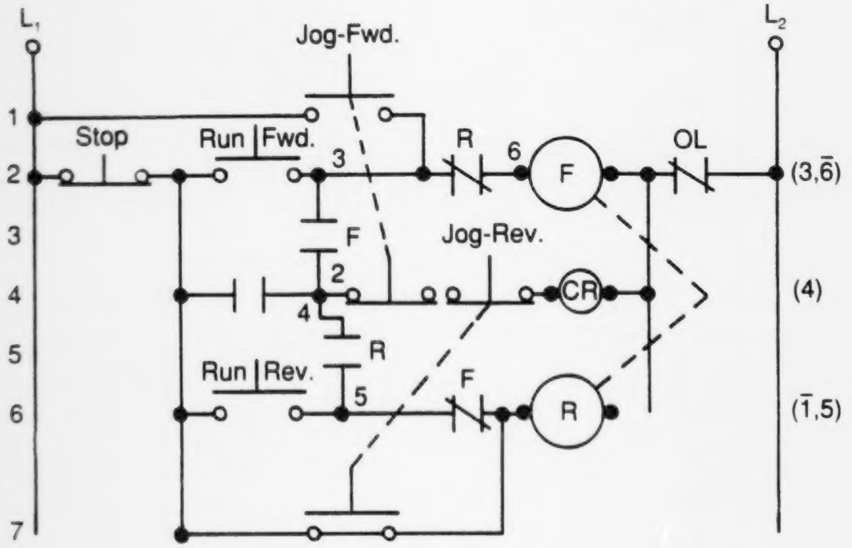
B. Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Wire a reversing starter with jog in both directions, using the following diagram.

Job Sheet 6


L₁
L₂
Jog-Fwd.
1
2
3
4
5
6
7
Stop
Run | Fwd.
Run | Rev.
3
R
6
F
OL
(3,6̄)
F
Jog-Rev.
2
4
CR
(4)
R
5
F
R
(1̄,5)

☐ 4. Have your instructor evaluate your job.

☐ 5. Disassemble the system.

☐ 6. Return tools and materials to proper storage.

☐ 7. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Special Control Circuits
Unit 14

Objective Sheet

Unit Objective

After completing this unit, the student should be able to design and build special control circuits. The student should demonstrate these competencies by completing the job sheets, and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to special control circuits with their correct definitions.
2. Identify the parts of a control relay.
3. List uses for control relays.
4. Identify the parts of a latching relay.
5. Describe the reason for using latching relays or contactors.
6. List types of timing relays.
7. Complete statements regarding applications for timing relays.
8. Describe how a ground fault indicator works.
9. Describe the use of an alarm silencing circuit.
10. Build a relay control circuit. (Job Sheet 1)
11. Wire a latching relay or contactor. (Job Sheet 2)
12. Wire a timed "on" circuit. (Job Sheet 3)
13. Wire a timed "off" circuit. (Job Sheet 4)
14. Energize three starters in a timed sequential order. (Job Sheet 5)
15. De-energize three starters in a timed sequential order. (Job Sheet 6)
16. Build a ground fault indicator circuit. (Job Sheet 7)

Special Control Circuits
Unit 14

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan for students with special needs.
4. Make copies of Teacher Supplement 1—Types of Control Relays.
5. Make transparencies from the transparency masters included with this unit. These appear in the teacher edition only and are designed to be used with the following objectives:

   TM 1—Typical Control Relay (Objective 2)
   TM 2—Latching Relay (Objective 4)
6. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.
7. Develop teaching plan. Adjust for different learning styles.
8. Make copies of Unit Evaluation Form.

Delivery and Application

9. Provide students with unit of instruction and teacher supplement.
10. Discuss unit and specific objectives.
11. Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
12. Discuss the job sheets. Review criteria for evaluation of these activities.

Evaluation

13. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

Suggested Activities

14. Make copies of the written test. Add or modify test items as needed.

15. Give written test.

16. Record job sheet ratings and written test scores on the Unit Evaluation Form. Add any additional assignments or supplemental activities that should be part of the unit evaluation.

17. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Invite a maintenance electrician to speak to the class about special controls. Skill area: **listening**.

2. Visit a local industry to view relays in use. Encourage students to ask questions and participate in a discussion of their observations after the visit. Skill area: **oral communication**.

3. Visit a supply house and view various relays or have examples to demonstrate in class.

Resources Used in Developing This Unit

1. Alerich, Walter N. *Electric Motor Control*, 4th Ed. Albany, NY: Delmar Publishers, Inc., 1988.

2. Kaltwasser, Stan and Gary Flowers. *Commercial and Industrial Wiring.* Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1988.

3. *National Electrical Code 1993.* Quincy, MA: National Fire Protection Association, 1992.

4. Rexford, Kenneth B. *Electrical Control for Machines*, 3rd Ed. Albany, NY: Delmar Publishers, 1987.

Suggested Activities

Suggested Supplemental Resources

1. Croft, Terrell and Wilford I. Summers. *American Electrician's Handbook*, 11th Ed. New York: McGraw-Hill Book Company, 1987.

2. Earley, Mark W., John M. Caloggero and Richard H. Murray. *NEC Handbook 1993.* Quincy, MA: National Fire Protection Association, 1992.

3. O'Riley, Ronald P. *Illustrated Changes in the 1993 National Electrical Code.* Albany, NY: Delmar Publishers, Inc., 1993.

Instructions for Evaluating Student Performance

Assignment Sheets—Be sure the student understands the criteria on which the evaluation is based. Assign a point value to each criterion and convert the total points to a percentage for grading.

Job Sheets—Be sure the student understands the criteria on which the evaluation is based. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher edition or student manual. Then observe the student performing the procedure. Rate both process and product.

> Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.
>
> Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. Complete the rating by assigning a point value to each criterion and by converting the point total to a percentage for grading. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Suggested Activities

Sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) which best fits your program needs.

Option A

4 - Skilled—Can perform job with no additional training.

3 - Moderately skilled—Has performed job during training program; limited additional training may be required.

2 - Limited skill—Has performed job during training program; additional training is required to develop skill.

1 - Unskilled—Is familiar with process, but is unable to perform job.

Option B

Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

Special Control Circuits
Unit 14

Answers to Written Test

1. a. 2 c. 4
   b. 1 d. 3

2. a. Normally closed contact
   b. Normally open contact
   c. Armature
   d. Coil terminals
   e. Coil

3. a. Control of fluid or pneumatic power valves
   b. Control of multiple circuits

4. a. Magnet
   b. Latch coil
   c. Armature
   d. Unlatch coil
   e. Baseplate
   f. Contacts
   g. Latch mechanism

5. To maintain contacts in their operated position during power off periods

6. a. Pneumatic timing relay
   b. Solid state timing relay
   c. Motor driven timing relay
   d. Timers

7. a. Accelerating
   b. Sequential start-up
   c. Energy management

8. When system has no grounds, both lights will glow at half brilliance. If a ground occurs, the light on the side without the ground will glow at full brilliance.

9. Alarms are used in industry to warn operators or other personnel of dangerous conditions. In an alarm condition an audible and visual signal are activated. The audible signal may be silenced, but the visual signal will remain on until the condition is cleared.

Special Control Circuits
Unit 14

Written Test

Name ______________________________ Score ______________

1. Match the terms on the right with their correct definitions.

   ______a. Relay whose timed contacts are operated through the action of a variable speed, extremely small motor

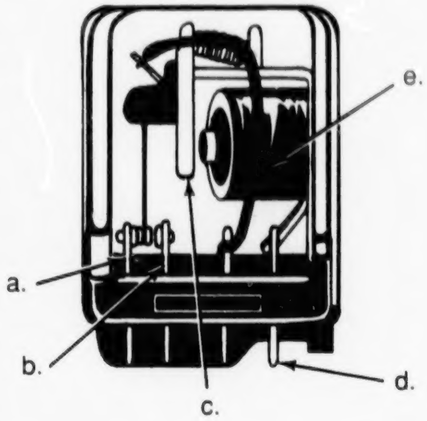
   ______b. Contactors or relays used in starting motors at low speed, then increasing to maximum speed in preset timed steps

   ______c. Relay whose timed contacts are operated by an electronic timer (microchip)

   ______d. Relay whose timed contacts are operated through the action of an air bellows and needle valve

   1. Accelerating contactors
   2. Motor driven timing relay
   3. Pneumatic timing relay
   4. Solid state timing relay

2. Identify the parts of the control relay shown below.



a. ______________________ d. ______________________

b. ______________________ e. ______________________

c. ______________________

Written Test

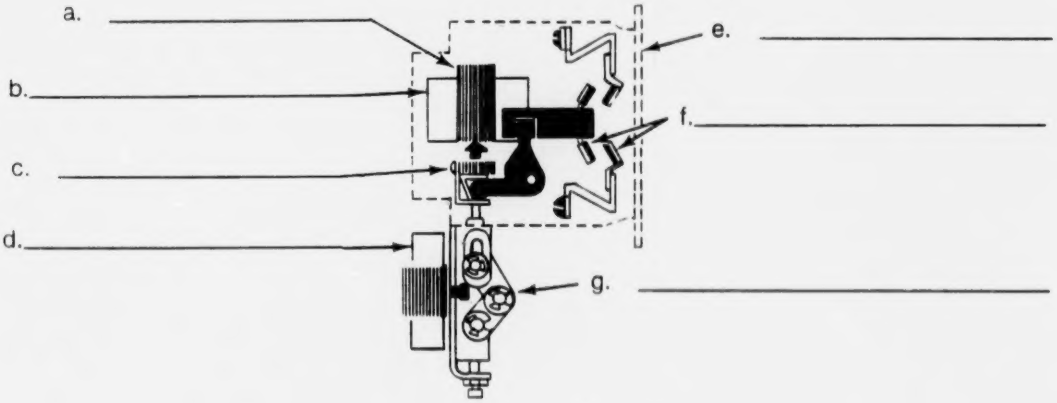
3. List two uses for control relays.

   a. ______________________________

   b. ______________________________

4. Identify the parts of the latching relay shown below.

Off Position



5. Describe the reason for using latching relays or contactors.

____

____

____

____

6. List four types of timing relays.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

Written Test

7. Complete the following statements regarding applications for timing relays by inserting the word(s) which best complete each application.

   a. To control the ____________ contactors of motor starters

   b. To control a timed ____________ ____________ of industrial machinery

   c. To sequence on large loads for ____________ ____________ systems

8. Describe how a ground fault indicator works.

   ____

   ____

   ____

   ____

9. Describe the use of an alarm silencing circuit.

   ____

   ____

   ____

   ____

   ____

   ____

***Permission to duplicate this test is granted.**

Special Control Circuits
Unit 14

Unit Evaluation Form

Student Name ______________________ Unit Rating ________

Job Sheet 1—Build a Relay Control Circuit Rating ______

Comments: ______________________________

____

Job Sheet 2—Wire a Latching Relay or Contactor Rating ______

Comments: ______________________________

____

Job Sheet 3—Wire a Timed "On" Circuit Rating ______

Comments: ______________________________

____

Job Sheet 4—Wire a Timed "Off" Circuit Rating ______

Comments: ______________________________

____

Job Sheet 5—Energize Three Starters in a Timed Sequential Order Rating ______

Comments: ______________________________

____

Job Sheet 6—De-Energize Three Starters in a Timed Sequential Order Rating ______

Comments: ______________________________

____

Job Sheet 7—Build a Ground Fault Indicator Rating ______

Comments: ______________________________

____

Unit Evaluation Form

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ____

____

Teacher Signature ______________________________ Date __________

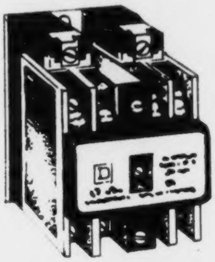
Student Signature ______________________________ Date __________

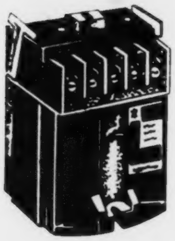
*Permission to duplicate this form is granted.

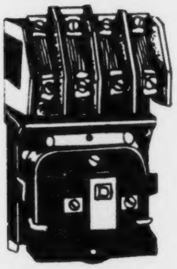
Special Control Circuits
Unit 14

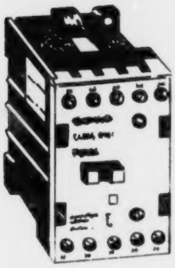
Teacher Supplement 1—Types of Control Relays

Industrial Control Relays

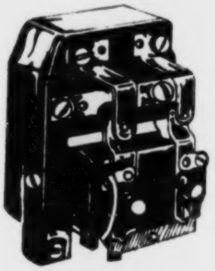

Type X

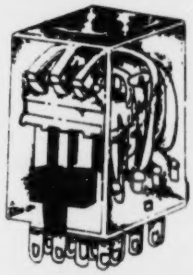

Type G

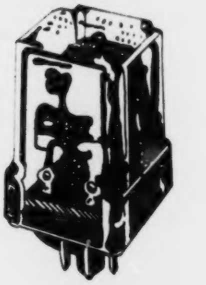

Type H

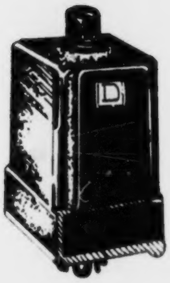

Type PH

General Purpose Control Relays


Type C


Type R


Type K

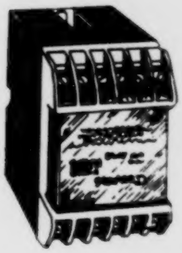

Type JCK

Teacher Supplement 1

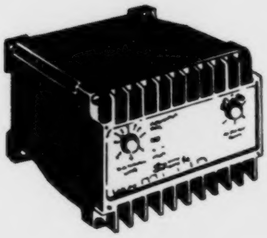
Specialty Relays

Intrinsically Safe Relay

Type DSC/DCS
Speed Control Relay



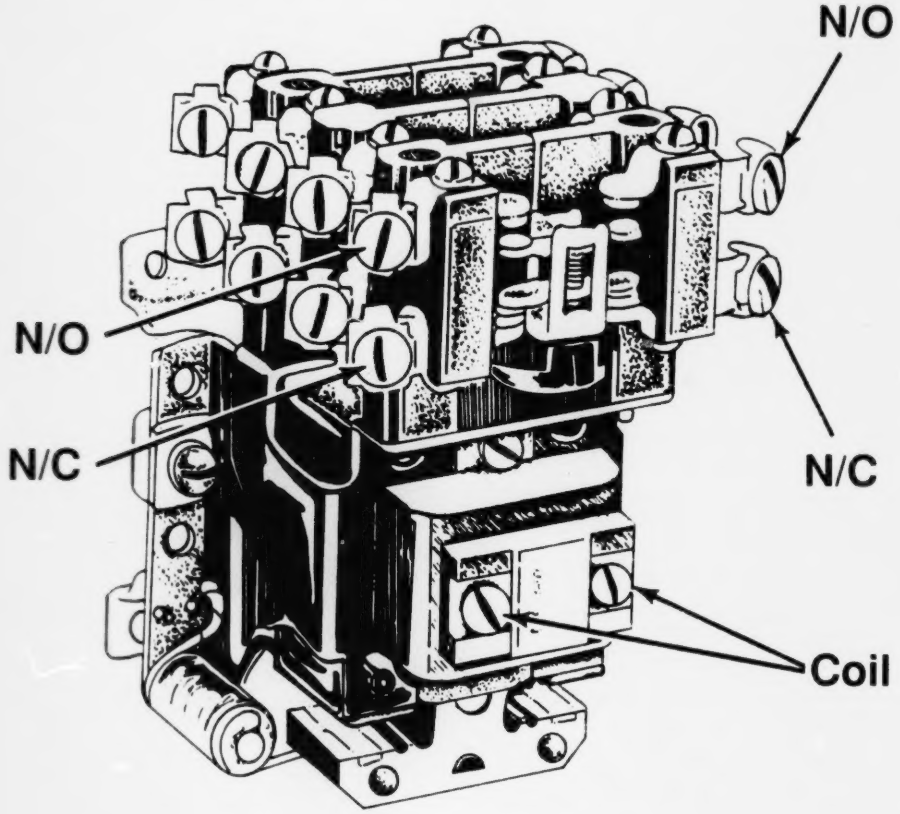
Barrier Relay

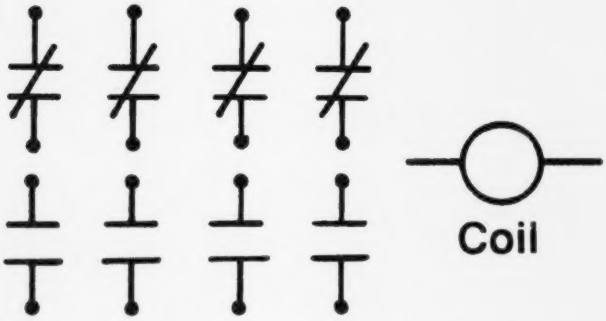


Type UBS
Undervoltage
Control Relay

Courtesy of Square D Company.

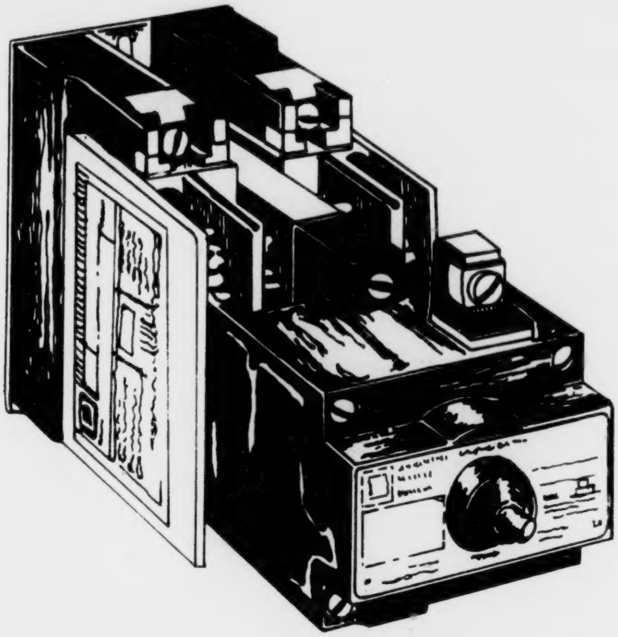
Typical Control Relay


N/O
N/O
N/C
N/C
Coil

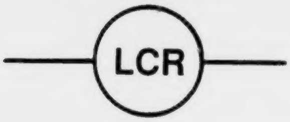


Courtesy of Square D Company.

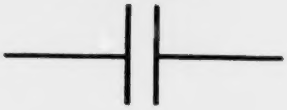
Latching Relay



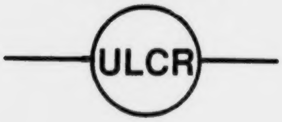
Latch Coil



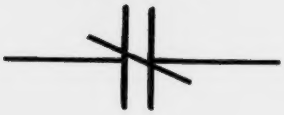
Normally Open Contact



Unlatch Coil



Normally Closed Contact



Courtesy of Square D Company.

Special Control Circuits
Unit 14

Information Sheet

1. **Terms and definitions**

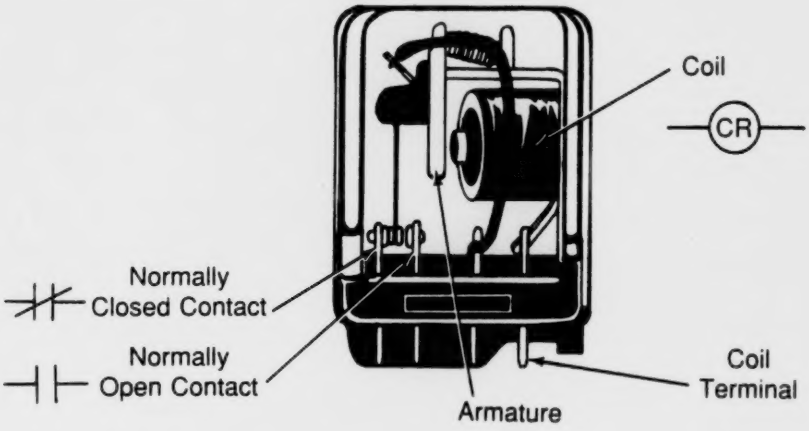
   a. **Accelerating contactors** — Contactors or relays used in starting motors at low speed, then increasing to maximum speed in preset timed steps

   b. **Motor driven timing relay** — Relay whose timed contacts are operated through the action of a variable speed, extremely small motor

   c. **Pneumatic timing relay** — Relay whose timed contacts are operated through the action of an air bellows and needle valve

   d. **Solid state timing relay** — Relay whose timed contacts are operated by an electronic timer (microchip)

2. **Parts of a control relay**


Coil
CR
Normally Closed Contact
Normally Open Contact
Armature
Coil Terminal

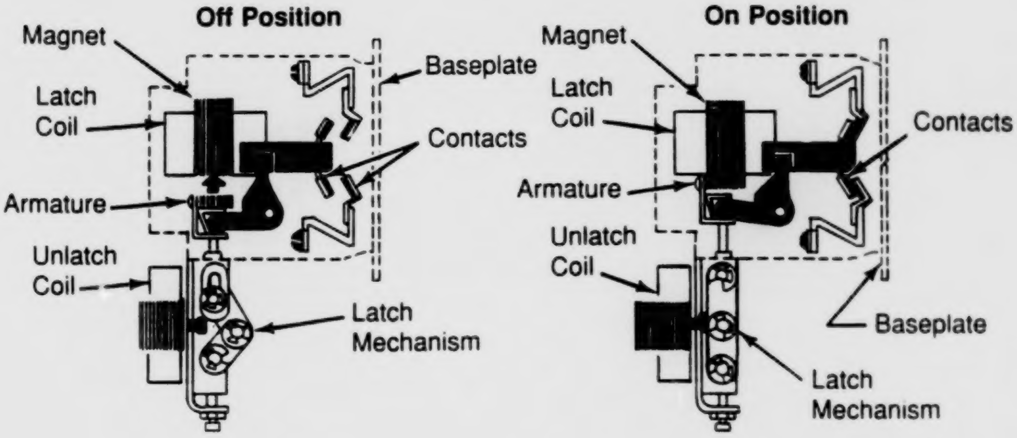
3. **Uses for control relays**

   a. Control of fluid or pneumatic power valves

   b. Control of multiple circuits

Information Sheet

4. **Parts of a latching relay or contactor**

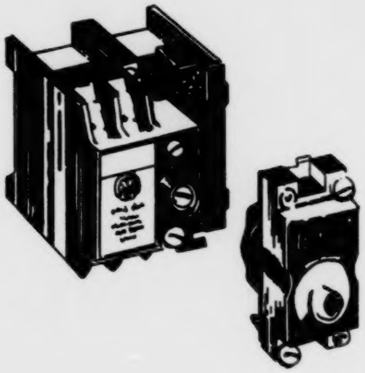

Off Position
Magnet
Latch Coil
Armature
Unlatch Coil
Baseplate
Contacts
Latch Mechanism
On Position
Magnet
Latch Coil
Armature
Unlatch Coil
Contacts
Baseplate
Latch Mechanism

5. **Reason for using latching relays or contactors** — To maintain contacts in their operated condition during power off periods

   Note: Some applications include lighting contactors or control circuits that must remain on until a specific event occurs.

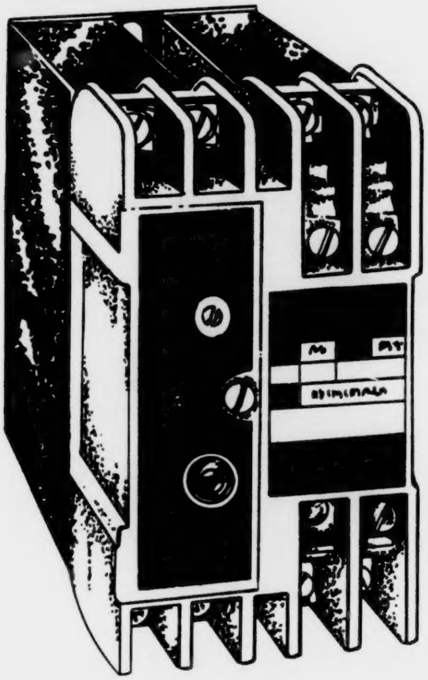
6. **Types of timing relays**

   a. Pneumatic timing relay

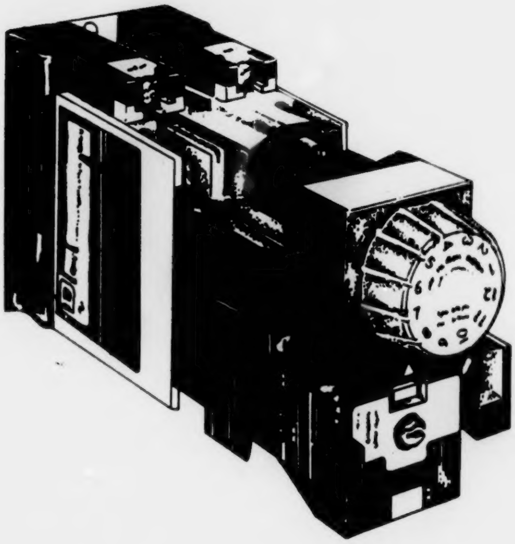


Information Sheet

b. Solid state timing relay

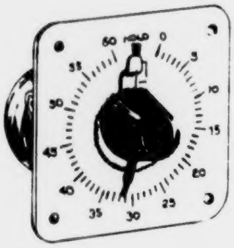


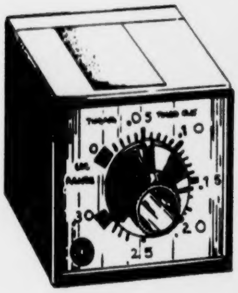
c. Motor driven timing relay

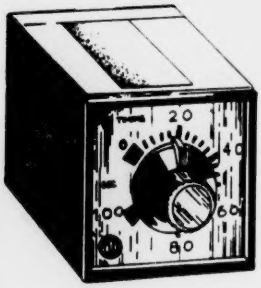


Information Sheet

d. Timers


60
HOLD
0
5
10
15
20
25
30
35
40
45
50
55


TIMING
.05
TIMED OUT
.10
.15
.20
.25
.30
0


TIMING
20
40
60
80
100
0

Note: Timers require a manual operation of the timer to start operation. The device will run the selected time, then stop automatically.

7. **Applications for timing relays**

   a. To control the accelerating contactors of motor starters

   b. To control a timed sequential start-up of industrial machinery

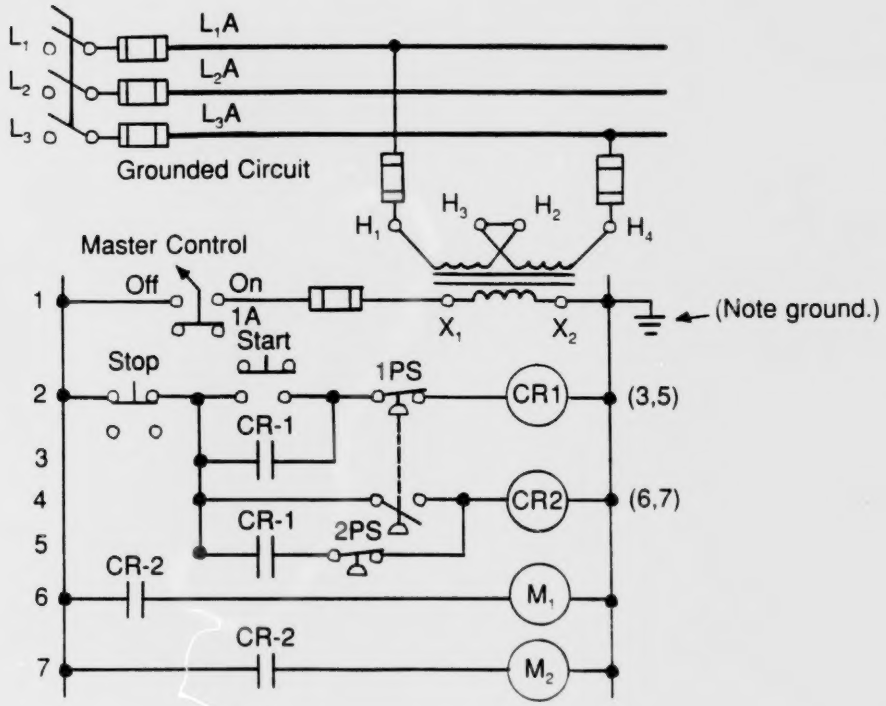
   c. To sequence on large loads for energy management systems

Information Sheet

8. Ground fault indicator circuits

a. If a ground fault occurs in the control circuit, the fuse will blow, disabling the machine.

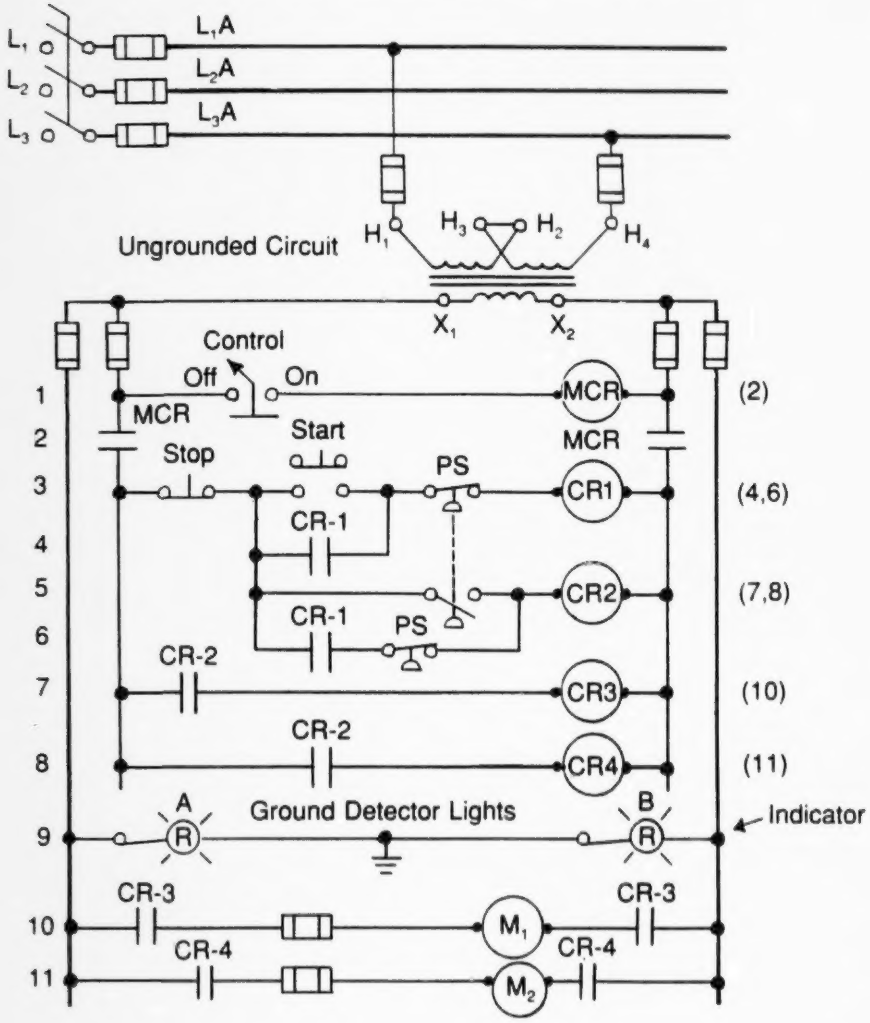
Conventionally Wired Control Circuit


L$_1$A
L$_2$A
L$_3$A
L$_1$
L$_2$
L$_3$
Grounded Circuit
H$_3$
H$_2$
H$_1$
H$_4$
Master Control
Off
On
1A
X$_1$
X$_2$
(Note ground.)
Start
Stop
1PS
CR1
(3,5)
CR-1
CR2
(6,7)
CR-1
2PS
CR-2
M$_1$
CR-2
M$_2$
1
2
3
4
5
6
7

b. When the system has *no* grounds, both lights will glow at half brilliance because they are connected in series. If a ground occurs, the light on the side without the ground will glow at full brilliance. The ground will be on the side with the non-functioning light. In most cases a ground can occur and the system will continue to operate.

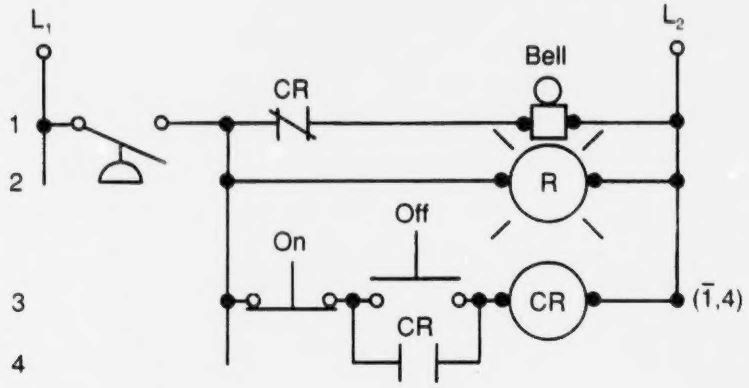
Note: This system is generally used on 208 or 480 volt wye systems with the lamps connected in a wye configuration.

Control Circuit with Ground Fault Indicator


L_1
L_2
L_3
L_1A
L_2A
L_3A
H_1
H_3
H_2
H_4
Ungrounded Circuit
X_1
X_2
Control
Off
On
1
MCR
(2)
2
MCR
Start
MCR
Stop
3
PS
CR1
(4,6)
CR-1
4
5
CR2
(7,8)
CR-1
PS
6
CR-2
7
CR3
(10)
CR-2
8
CR4
(11)
A
Ground Detector Lights
B
9
R
R
Indicator
CR-3
CR-3
10
M_1
CR-4
CR-4
11
M_2

Information Sheet

9. **Use of an alarm silencing circuit** — Alarms are commonly used in industry to warn operators or other personnel of hazardous or dangerous conditions. Normally, the alarm will consist of an audible signal such as a horn or bell, and a visual signal such as a warning light. In this case, when an alarm condition occurs, the audible and visual alarms will activate and the maintenance personnel will silence the audible signal, but the visual signal will remain until the condition has been corrected.



Note: The push-button operators located on rung 3 are normally labeled "stop" and "start". In this case, however, they are labeled to describe their function in the circuit. If the bell and the light become energized in response to an increase in pressure, the "off" button can be used to silence the bell. The "on" button will allow the bell to ring if it is pressed. The light, however, can only be canceled in response to a decrease in pressure.

Special Control Circuits
Unit 14

Job Sheet 1—Build a Relay Control Circuit

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Ladder diagram correct	______
Explanation correct	______
System operates	______
Demonstrated good workmanship	______
Complied to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
Four 120 volt pilot lights
Four 4-pole relays with 120 volt coils (N/O)
N/C push button
Four N/O push buttons
20 feet of #16 THWN

B. Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Design a control system to solve the following scenario problem:

Job Sheet 1

A contest for industrial electricity students has been organized to test the students over *National Electrical Code* knowledge. Four students will participate. Each will be seated at a desk containing a push button station. A question will be asked by the facilitator. The first contestant with the answer will press the push button that will energize a pilot light in front of the desk. It will also lock out the other three contestants' lights. The facilitator, upon receiving a correct response to the question, may then reset the system by pressing another push button. You have been asked to design and build the control system. Draw a diagram of your design in the space provided below.

☐ 4. Draw a ladder diagram of your control system in the space provided below. (Be sure to reference your diagram.)

Job Sheet 1

☐ 5. In complete sentences, explain in detail how your system operates.

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☐ 6. Have your instructor approve your diagram and explanation.

☐ 7. Build a prototype of the system.

☐ 8. Have your instructor evaluate the job.

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Special Control Circuits
Unit 14

Job Sheet 2—Wire a Latching Relay or Contactor

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	_____
Circuit operates correctly	_____
Demonstrated good workmanship	_____
Complied to *NEC*	_____

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
4-pole latching relay (2 N/O - 2 N/C) (120 volt coils)
Two N/O push buttons and enclosures
Pilot light (120 volt) and enclosures
10 feet of #14 THHN
Six #10 x 1" sheet metal screws
Mounting board

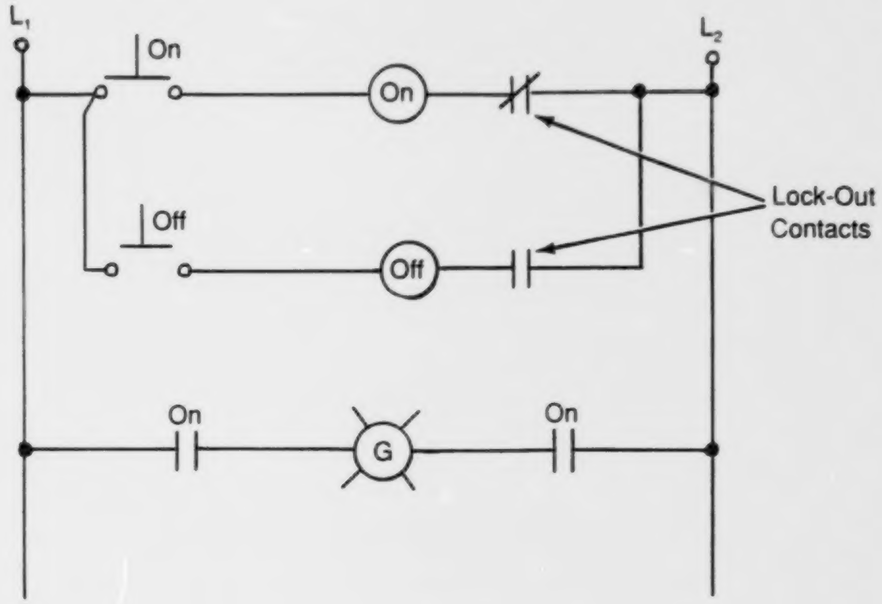
B. Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

Job Sheet 2

☐ 3. Using the following diagram, wire a latching relay to operate a lighting load.


L_1
L_2
On
On
Off
Off
Lock-Out Contacts
On
G
On

☐ 4. Have your instructor evaluate the job.

☐ 5. Disassemble the system.

☐ 6. Return tools and materials to proper storage.

☐ 7. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Special Control Circuits
Unit 14

Job Sheet 3—Wire a Timed "On" Circuit

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Explanation correct	______
System operates	______
Demonstrated good workmanship	______
Complied to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
Time delay relay with timed closed contacts (120 volt coil)
Three-phase motor starter (120 volt coil)
Start/stop station
Eight #10 x 1" sheet metal screws
Mounting board
15 feet of #16 THHN

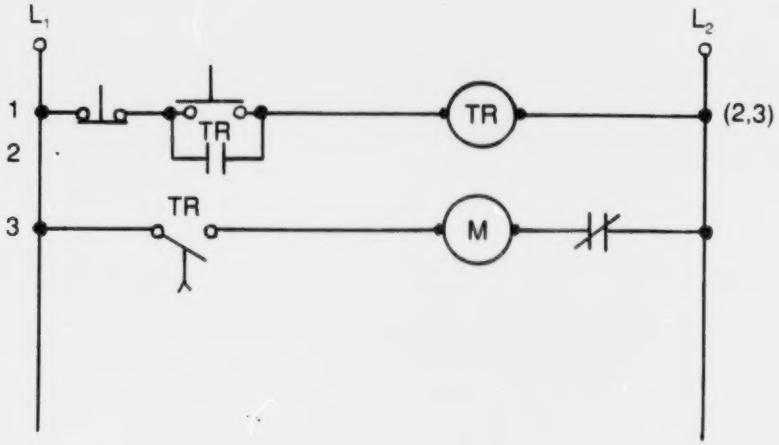
B. Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

Job Sheet 3

☐ 3. Using the following diagram, build an "on" delay circuit.



☐ 4. In complete sentences, explain the sequence of operation of the circuit.

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☐ 5. Have your instructor approve your explanation.

☐ 6. Build the circuit.

☐ 7. Have your instructor evaluate your job.

☐ 8. Disassemble the system.

Job Sheet 3

☐ 9. Return tools and materials to proper storage.

☐ 10. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Special Control Circuits
Unit 14

Job Sheet 4—Wire a Timed "Off" Circuit

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Explanation correct	______
Circuit operates correctly	______
Demonstrated good workmanship	______
Complied to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
Time delay relay with timed open contacts (120 volt coil)
General purpose relay (120 volt coil)
Three-phase motor starter
Two N/O push buttons with enclosure
N/C push button with mushroom head and enclosure
Ten #10 x 1" sheet metal screws
Mounting board
15 feet of #16 THHN
2µF 300 volt nonelectrolytic capacitor

B. Procedure

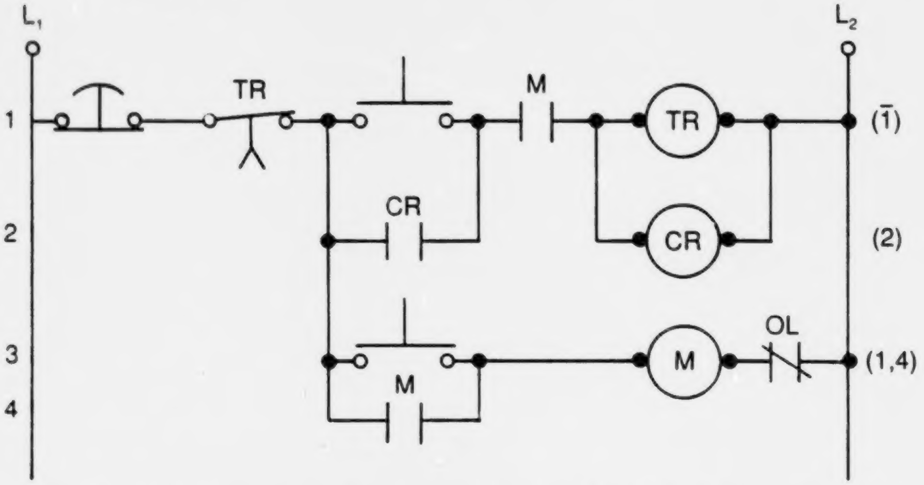
☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

Job Sheet 4

☐ 3. Using the following diagram, build an "off" delay circuit.

Note: Any time an off delay is used, an emergency shutdown button must be installed.



Note: In many cases it may be necessary to parallel a 1 to 2 micro-Farad non-electrolytic capacitor with the timing relay. If the circuit tends to restart after the reclosure of contact TR on rung 1, the capacitor will be necessary to hold the contact open longer.

☐ 4. In complete sentences, explain the sequence of operation of the circuit.

☐ 5. Have your instructor approve your explanation.

☐ 6. Build the circuit.

Job Sheet 4

☐ 7. Have your instructor evaluate your job.

☐ 8. Disassemble the system.

☐ 9. Return tools and materials to proper storage.

☐ 10. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Special Control Circuits
Unit 14

Job Sheet 5—Energize Three Starters in a Timed Sequential Order

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Ladder diagram correct	______
Explanation correct	______
System operates	______
Demonstrated good workmanship	______
Complied to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
Two time delay relays (NOTC) 120 volt coil
Three 3ϕ starters, 120 volt coils
N/O push button
N/C push button
Three-element control station
Mounting board
Twenty #10 x 1" sheet metal screws
20 feet of #16 THHN

B. Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

Job Sheet 5

☐ 3. Design and draw a ladder diagram of a circuit to act as follows:

a. Depress start.

1) Starter 1 energizes instantly.

2) 10 second delay, then starter 2 energizes.

3) 10 second delay, then starter 3 energizes.

b. Depress stop — All systems de-energize.

☐ 4. In complete sentences, write a detailed explanation of how your system operates.

Job Sheet 5

☐ 5. Have your instructor evaluate your diagram and explanation.

☐ 6. Build the circuit.

☐ 7. Have your instructor evaluate your job.

☐ 8. Retain circuit for use in Job Sheet 6.

☐ 9. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Special Control Circuits
Unit 14

Job Sheet 6—De-Energize Three Starters in a Timed Sequential Order

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Ladder diagram correct	______
Explanation correct	______
Circuit operates correctly	______
Demonstrated good workmanship	______
Complied to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
Circuit from Job Sheet 5
N/O push button
Three time delay relays (NOTC) 120 volt coil
Six #10 x 1″ sheet metal screws
10 feet of #16 THHN

B. Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

Job Sheet 6

☐ 3. Revise the diagram from Job Sheet 5 to act as follows:

   a. Depress start.

      1) Starter 1 energizes instantly.

      2) 10 second delay, then starter 2 energizes.

      3) 10 second delay, then starter 3 energizes.

   b. Depress stop.

      1) Starter 3 de-energizes instantly.

      2) 10 second delay, then starter 2 de-energizes.

      3) 10 second delay, then starter 1 de-energizes.

   c. Depress emergency stop — All systems de-energize.

Job Sheet 6

☐ 4. In complete sentences, write a detailed explanation of how your system operates.

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☐ 5. Have your instructor evaluate your diagram and explanation.

☐ 6. Build the circuit.

☐ 7. Have your instructor evaluate your job.

☐ 8. Disassemble the system.

☐ 9. Return tools and materials to proper storage.

☐ 10. Clean the work area.

Evaluator's Comments: ________________________________

____

____

Special Control Circuits
Unit 14

Job Sheet 7—Build a Ground Fault Indicator Circuit

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
Practiced safety rules throughout procedure	______
Ladder diagram correct	______
Circuit operates correctly	______
Demonstrated good workmanship	______
Complied to *NEC*	______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the above criteria.

A. Tools and materials

Pouch tools
Control transformer 240/120 volt
Three-phase starter
Start/stop station
Two 120 volt pilot lights and 2-element enclosure
Eight #10 x 1" sheet metal screws
15 feet of #16 TFF
Mounting board
240 volt power source
Two fuse holders
Two 6/10 amp fuses

B. Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

Job Sheet 7

☐ 3. Design and draw a ladder diagram of a three-wire control system to operate a three-phase starter. The control circuit should be equipped with a ground fault indicator.

☐ 4. Have your instructor approve your diagram.

☐ 5. Build the circuit.

☐ 6. Have your instructor evaluate your job.

☐ 7. Disassemble the system.

☐ 8. Return tools and materials to proper storage.

☐ 9. Clean the work area.

Evaluator's Comments: ______________________________

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Programmable Controllers
Unit 15

Objective Sheet

Unit Objective

After completing this unit, the student should be able to understand programmable controllers and distinguish between common input/output devices. The student should demonstrate these competencies by completing the assignment sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to programmable controllers with their correct definitions.
2. Select from a list programmable controller functions.
3. List the three stages necessary to control a process.
4. Identify input devices.
5. Identify output devices.
6. Identify components of a programmable controller.
7. Complete statements concerning states of contacts.
8. Name types of input/output modules.
9. Identify the parts of an optical coupler.
10. Identify the basic PC ladder logic symbols.
11. Explain why a stop button is wired normally closed.
12. List the basic numbering systems used in programmable controllers.
13. Match I/O devices with their functions. (Assignment Sheet 1)
14. Convert between numbering systems. (Assignment Sheet 2)

Programmable Controllers
Unit 15

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan for students with special needs.
4. Make copies of Teacher Supplement 1—Glossary.
5. Make transparency from the transparency master included with this unit. This appears in the teacher edition only and is designed to be used with the following objective:

   TM 1—Application of Programmable Controllers (Objective 2)

6. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.
7. Develop teaching plan. Adjust for different learning styles.
8. Make copies of Unit Evaluation Form.

Delivery and Application

9. Provide students with unit of instruction and teacher supplement.
10. Discuss unit and specific objectives.
11. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
12. Discuss the assignment sheets. Review criteria for evaluation of these activities.

Evaluation

13. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.
14. Make copies of the written test. Add or modify test items as needed.

Suggested Activities

15. Give written test.

16. Record assignment sheet ratings and written test scores on the Unit Evaluation Form. Add any additional assignments or supplemental activities that should be part of the unit evaluation.

17. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Visit an industry that uses programmable controllers. Encourage students to ask questions to clarify information that is given. Skill area: **oral communication**.

2. Have PC sales engineers demonstrate their product line. Discuss with the class any advantages or disadvantages they may have observed about the product. Skill area: **oral communication**.

3. Show examples of input and output devices to class.

4. Provide students with catalogs describing various types of programmable controllers and their specific features.

   Examples: Telemecanique, Square D

5. Explain the different numbering systems and how they may apply to programmable controllers. Have students practice converting between number systems. Skill area: **math**.

6. Design lessons specific to the PC used at your facility.

   Note: Due to the varied brands and types of programmable controllers used in the different training facilities, it is impossible to include any job sheets in this unit. It is suggested that each instructor develop a series of job sheets designed to instruct the student in the step by step use of the PC manuals. Job sheets should begin with extremely simple programs and progress to scenario type jobs including all the previously learned steps.

Suggested Activities

Resources Used in Developing This Unit

1. Kaltwasser, Stan and Gary Flowers. *Commercial and Industrial Wiring*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1988.
2. Rexford, Kenneth B. *Electrical Control for Machines*, 3rd Ed. Albany, NY: Delmar Publishers, 1987.
3. *Tel-A-Train Workbook for PCs*. Chattanooga, TN: Tel-A-Train, Inc.

Suggested Supplemental Resources

1. Catalog. Palatine, IL: Square D Co. (Available from Square D Co., 1415 So. Roselle, Palatine, IL 60067; 708/397-2600)
2. Catalog. Owings Mills, MD: Telemecanique Inc. (Available from Telemecanique Inc., 10065 Red Run Blvd., Owings Mills, MD 21117; 301/581-2000)
3. *National Electrical Code 1993*. Quincy, MA: National Fire Protection Association, 1992.
4. *Programmable Controllers*. (Film—seven-part series.) Chattanooga, TN: Tel-A-Train, Inc.

Instructions for Evaluating Student Performance

Assignment Sheets—Be sure the student understands the criteria on which the evaluation is based. Assign a point value to each criterion and convert the total points to a percentage for grading.

Job Sheets—Be sure the student understands the criteria on which the evaluation is based. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher edition or student manual. Then observe the student performing the procedure. Rate both process and product.

> Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.

Suggested Activities

Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. Complete the rating by assigning a point value to each criterion and by converting the point total to a percentage for grading. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) which best fits your program needs.

Option A

4 - Skilled—Can perform job with no additional training.
3 - Moderately skilled—Has performed job during training program; limited additional training may be required.
2 - Limited skill—Has performed job during training program; additional training is required to develop skill.
1 - Unskilled—Is familiar with process, but is unable to perform job.

Option B

Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

Programmable Controllers
Unit 15

Answers to Assignment Sheets

Assignment Sheet 1

A. 1
B. 3
C. 4
D. 2

Assignment Sheet 2

A. 0000-0111-1000
B. 0100-1001-0011
C. 0010-0000-0110
D. 1000-0101-0001
E. 516
F. 392
G. 287
H. A9F
I. 7DC
J. 65B

Programmable Controllers
Unit 15

Answers to Written Test

1.

a.	2	e.	9	i.	4
b.	3	f.	1	j.	7
c.	6	g.	8		
d.	5	h.	10		

2. a, c, d, f

3. a. Input
   b. Logic
   c. Output

4. a. Limit switches
   b. Proximity switches
   c. Fiber optic probe
   d. Thumbwheel
   e. Push buttons

5. a. Motor starters
   b. Contactors and relays
   c. Counters

6. a. Controller
   b. Input modules
   c. Output modules
   d. Programmer

7. a. Inactive
   b. Inactive
   c. Activated

8. a. Discrete
   b. Numerical
   c. Analog

9. a. Optical coupler
   b. Triac
   c. Gate

10. a. Normally open (examine on)
    b. Normally closed (examine off)
    c. Normal output coils
    d. Latched output coils

Answers to Written Test

11. The N/C input is passing power to the I/O module. Sensing this voltage, the I/O sends an "on" signal to the controller.

12. a. Decimal
    b. Binary
    c. Octal
    d. Hexidecimal

Programmable Controllers
Unit 15

Written Test

Name ____ Score ________________

1. Match the terms on the right with their correct definitions.

______a. A logic element in a PC user program that is used to simulate the operation of electromechanical counters

______b. A two-state reference in the user program that can be either on or off

______c. A system that contains digital switching functions, circuits, or devices

______d. A signal that provides the controller information about the system; can be discrete, numeric, or analog

______e. A device designed to allow inserting, monitoring, and editing a user program in the PC

______f. A signal that varies proportionally with some aspect of the environment

______g. A signal coming from the controller to field devices; can be discrete, numeric, or analog

______h. A solid state control system that contains a user programmable memory for the storage of instructions to perform specific functions in an operation

______i. Transfer of discrete signals through glass fibers with light

______j. Tying in of multiple PCs to communicate with each other in the performance of a process

1. Analog signal
2. Counter
3. Discrete
4. Fiber optics
5. Input
6. Logic
7. Networking
8. Output
9. Programmer
10. Programmable controller

Written Test

2. Select from the following list programmable controller functions by placing an "X" in the blank preceding each correct function.

______a. The control of dangerous devices or devices in a dangerous environment

______b. Eliminating the need for retraining employees

______c. The facilitation of the change of a process at minimum expense and down time

______d. The performance of arithmetic operations that might be required for controlling certain operations

______e. Facilitation of 24-hour production of a product

______f. Fault locating, alarming, and regulation of devices that rarely need attention

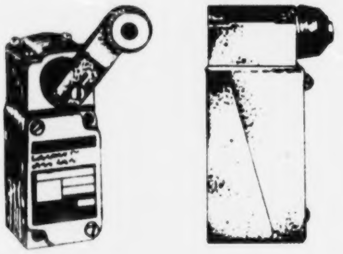
3. List the three stages necessary to control a process.

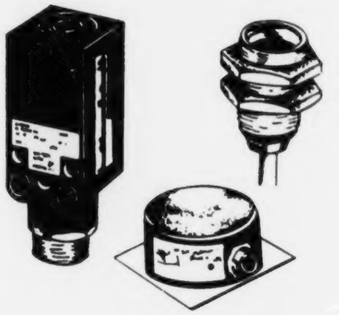
a. ______________________________

b. ______________________________

c. ______________________________

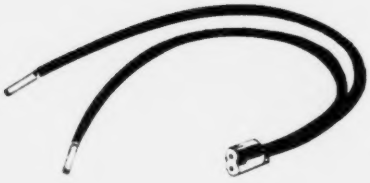
4. Identify the following input devices.

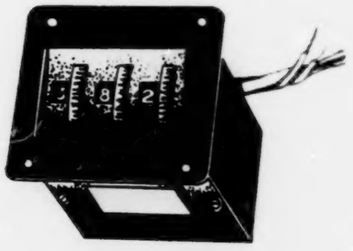




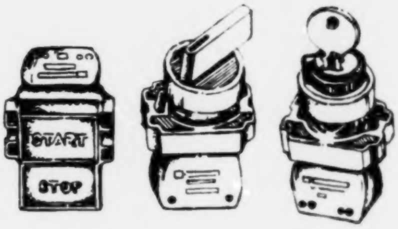
a. ____________________ b. ____________________

Written Test



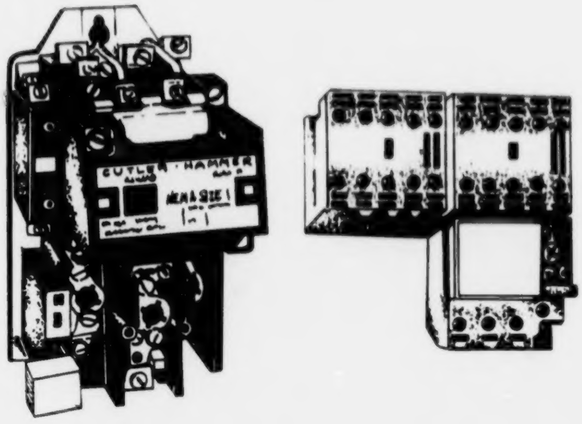


c. ______________________ d. ______________________



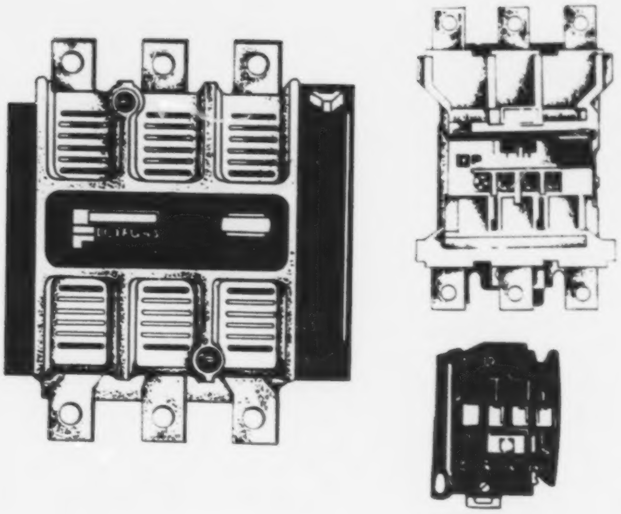
e. ______________________

5. Identify the following output devices.

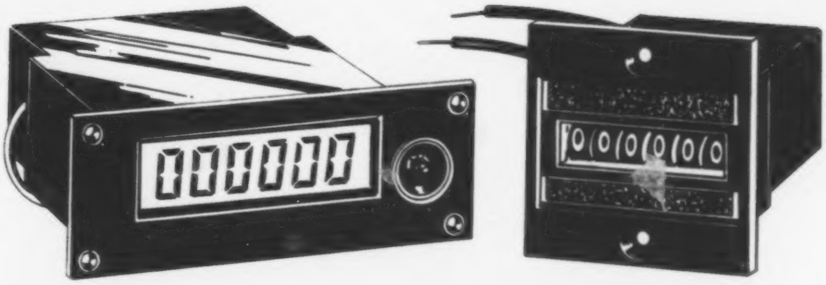

CUTLER-HAMMER
NEMA SIZE 1

a. ______________________

Written Test



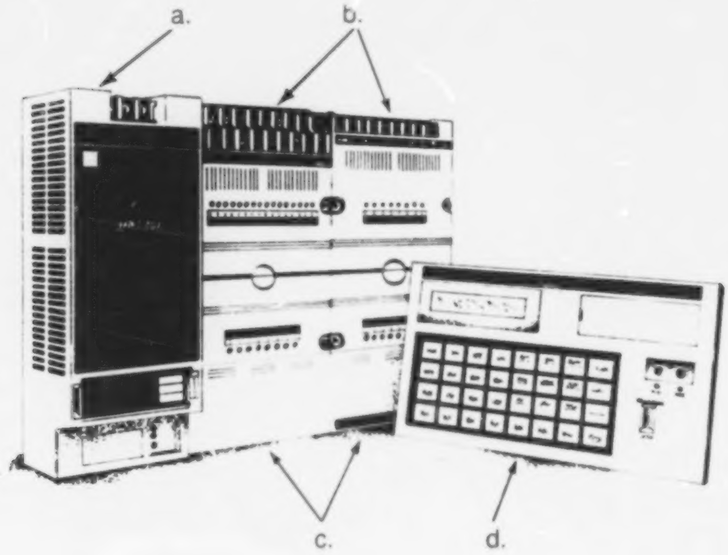
b. ______________________________


000000
000000

c. ______________________________

Written Test

6. Identify the components of the programmable controller shown below.



a. ______________________ c. ______________________

b. ______________________ d. ______________________

7. Complete the following statements concerning states of contacts.

   a. A normally closed contact will be closed and passing power when it is ____________.

   b. A normally open contact will be open and not passing power when it is ____________.

   c. When ____________, contacts change to the opposite state from their normal state.

8. Name three types of input/output modules.

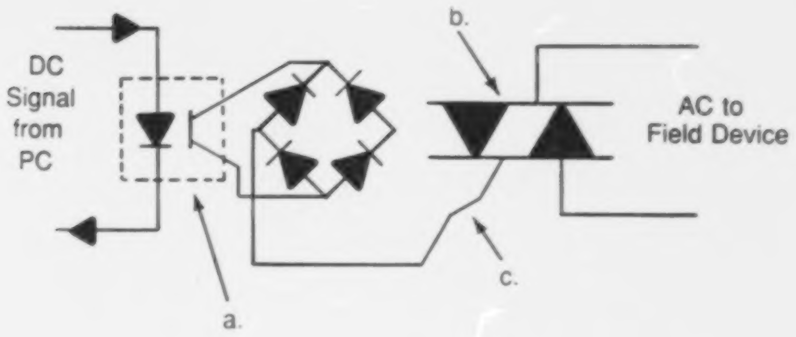
   a. ____

   b. ____

   c. ____

Written Test

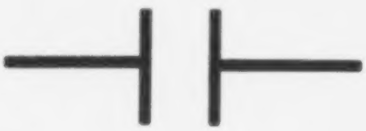
9. Identify the parts of the optical coupler shown below.


DC
Signal
from
PC
AC to
Field Device
a.
b.
c.

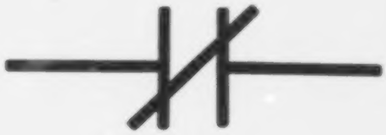
a. ____________________ b. ____________________

c. ____________________

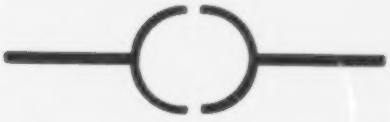
10. Identify the basic PC ladder logic symbols shown below.



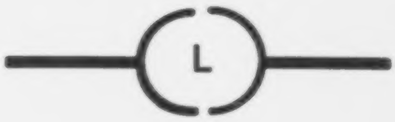
a. ____________________



b. ____________________



c. ____________________



d. ____________________

Written Test

11. Explain why a stop button is wired normally closed.

____

____

____

____

12. List the basic numbering systems used in programmable controllers.

a. ____

b. ____

c. ____

d. ____

***Permission to duplicate this test is granted.**

Programmable Controllers
Unit 15

Unit Evaluation Form

Student Name ______________________ Unit Rating __________

Assignment Sheet 1—Match I/O Devices with Their Functions Rating ______

Comments: ____

____

Assignment Sheet 2—Convert Between Numbering Systems Rating ______

Comments: ____

____

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ____

____

Teacher Signature ______________________ Date __________

Student Signature ______________________ Date __________

*Permission to duplicate this form is granted.

Programmable Controllers
Unit 15

Teacher Supplement 1—PC Glossary

Note: The following glossary has been reprinted with permission of Tel-A-Train, Inc., Chattanooga, Tennessee.

A

Abort: a signal to terminate the current process.

Active Light: (see Status Light)

Address: a coded value used to identify a specific I/O Channel or Module, or the location of a Register in Memory.

Alphanumeric: series of characters, usually code, which contain a combination of letters, numerals, and/or special characters. e.g. B678$.

Analog Signal: a signal which varies proportionally with some aspect of the environment, e.g., the signal from a pressure transducer which varies with the amount of pressure being applied.

Analog I/O Module: an I/O Module which performs Analog-to-Digital (Input) or Digital-to-Analog (Output) conversions so that the Controller can communicate with Analog Field Devices.

And Circuit: a Series Circuit which allows power flow in the Logic only when all the conditions have been met.

ANSI: American National Standards Institute.

Application Program: (see User Program)

Arithmetic Function: a function which compares the contents of two or more registers arithmetically (addition, subtraction, multiplication, division, etc.) and may take action as a result.

ASCII: standard alphanumeric characters established by the American Standards Institute.

B

Baud: the number of bits transmitted every second.

BCED (Binary-Coded Decimal): a system which uses four Binary Digits to represent each Decimal Digit (0-9) in a Decimal Number.

Binary: a numeric, base 2 system which uses values represented only by the numbers 0 and 1 (OFF/ON).

Bit: contraction for Binary Digit. A single digit whose value can be either 0 or 1. The smallest division of a PC word.

Bugs: software errors which cause unwanted behavior, or functional problems due to faulty hardware.

Bus: an electronic channel used to send or receive data.

Byte: a string of Binary Digits operated on as a unit. Unless otherwise specified, a byte normally contains eight bits.

C

Cascading Functions: connecting two or more Functions together to control one Output. Timers and Counters can be Cascaded together to produce results which cannot be achieved using one Counter or one Timer.

Channel: a group of I/O Modules that are separately connected to the Controller.

Checksum: an error detection technique which adds up the Bytes or Words of data and compares them.

Chip: a very small section of semiconductor material, usually made of silicon, containing electronic circuits.

Clear: to return Memory to a nonprogrammed state.

CMOS Memory: an advanced form of semi-conductor Memory which requires very little DC Power to retain its contents.

Code: programmed instructions.

Coil: an element in the logic program which will react in a discrete manner to the operations performed by the Programmable Controller. Its ON and OFF status can be output to the real world via an Output Module, and it may be used in other logical operations. Coils are normally turned OFF when power is removed from the Controller. (see Latched Coil)

Computer: a device which has a CPU, Memory, I/O Facilities, and a Power Supply. It accepts information, processes the data in a programmed manner, and gives you a result.

Computer Interface: circuitry which allows a Controller's Processor to communicate with a computer.

Contact: 1. the junction point on a ladder rung which when closed allows a complete path for power flow. 2. the points on a Relay which open or close when the Relay coil is Energized.

Counter: a logic element in a PC User Program which is used to simulate the operation of electro-mechanical Counters.

CPU (Central Processing Unit): the "brain" of the Controller System, consisting of the power supply, memory, and processor. All logic solving and decision making are performed here by the Processor. May also be called the MAINFRAME. Some-times the term "CPU" is used to refer only to the Processor.

CRT: a cabinet containing a Cathode Ray Tube to display programs such as Ladder Logic Diagrams. The CRT might also be used to display data lists and application reports.

Cursor: a visible movable pointer on a CRT or Programming Panel which indicates where an instruction is to be entered or an edit is to be made.

Teacher Supplement 1

D

Diagnostic Program: a test program you can use to help isolate hardware problems in the PC and Application Equipment.

Digital: having discrete states. Digital Logic can have up to 16 states. However, most Digital Logic is Binary Logic with two states, ON and OFF.

Disable: the ability to disconnect a Coil or discrete Input from its normal control. Usually done prior to Forcing. (see Forcing)

Discrete Reference: a two-state reference in the User Program which can be either ON or OFF. A discrete reference can be an Input, Output, or Internal Logic Element.

Disk Drive: a device used to read and write data on a magnetic disk.

Diskette: thin magnetically sensitive material which is placed in a Disk Drive for the purpose of storing data and loading the memory contents of a computer.

Documentation: an orderly collection of data and diagrams explaining the hardware and software involved in a Control System.

Down Load: transferring the User Program from the Controller to some other device, usually a programming device.

Dump: recording the entire contents of User Memory onto a storage medium (e.g., magnetic tape, floppy disk, etc.)

E

EAROM: Electrically Alterable Read-Only Memory.

Edit: to deliberately modify the user program.

EEPROM: Electrically Erasable Programmable Read-Only Memory.

EIA: Electronic Industries Association, an agency which sets standards in electronics.

Element: the basic building block of the PC ladder logic diagram. An element might be a relay contact, a horizontal short, a vertical short, a fixed numeric value, register reference, coil, or higher function. These are sometimes called logic elements.

Enable: to reconnect a logic coil or discrete input after it has been disabled. The opposite of "Disable."

EPROM: Erasable Programmable Read-Only Memory. This type of ROM can be erased with ultraviolet light and then reprogrammed.

Executive (Memory): an operating system which processes the User Program.

F

FIFO Operation: data management which assures that the First In will be the First Out.

Force: the operation which can be done to change a reference's status. The reference can be changed from OFF to ON or ON to OFF. This allows you to energize or not energize an Output by means of the Programming Device to aid in troubleshooting.

H

Hard Copy: a printed copy of information from a computer, such as a Ladder Logic Program listing.

Hardware: the mechanical, electrical, and electronic devices which make up a complete Programmable Controller System.

Holding Register: a storage block of the memory which holds a value and can be accessed through its Address.

Hexidecimal: the base 16 Number System often used to present error codes to the User.

I

Image Table: a table in the Memory which contains the status of all Inputs, Coils, and Registers.

Input: a signal which provides the Controller information about the system. It can be discrete (pushbutton, relay contacts, limit switches, etc.) or Numeric (thumbwheel, external solid-state device, etc.), or Analog.

Input Field Devices: devices which supply data to the PC.

Input Module: a device which connects the Controller with Input Devices. The Input Module contains the circuitry required to convert the incoming signals to voltages which can be used by the PC.

I/O: Input/Output, the Controller's connection to the field devices; includes both discrete and register signals.

Isolated I/O: designed to enable the connection of field devices powered from different sources to a single module; this type of I/O is electrically isolated from all other circuits in the Module.

Interface: circuitry which allows communication between the Processor and the Field.

L

Ladder Diagram: an industry standard for representing Control Logic along Rungs in a ladder arrangement and using relay equivalent symbology.

Ladder Listing: a hard copy listing of the User Logic Program.

Latched Coil: a type of Coil which will return to its last state after a power failure has been rectified. These Coils are unlike normal Coils which reset to OFF at Powerup. (see "Retentive" if your Controller allows this function.)

LCD (Liquid Crystal Display): a reflective visual readout which offers the advantage of extremely low power consumption.

LED: Light Emitting Diode.

Logic: a system which contains digital switching functions, circuits, or devices, as in Programmable Controllers.

Logic Diagram: a graphic representation of Logic Functions and conditions.

Logic Element: any one of the symbols or functions which can be used in a Ladder Logic Diagram.

M

Machine Language: a Program which has been written in Binary.

Mainframe: (see Processor)

Memory: storage area for Binary Data and Programs.

Memory Map: a diagram which shows where in the Controller's Memory various kinds of data are held.

Memory Protect: a hardware feature usually under keylock control which prevents a portion of the Memory from being altered by an external device.

Microprocessor: the control and processing section of a small Computer.

Microsecond: one millionth of a second.

Millisecond: one thousandth of a second.

Modem: a device which converts digital signals to analog signals suitable for transmission over a telephone line and vice-versa.

Move Function: the capability, in some PCs, which allows data to be transferred from a Register to a Table and from a Table to a Register.

Multiplexing: the ability to transfer a number of different data signals through a single channel.

N

Network: a group of logic elements which has been connected together to perform a single function. In some Controllers, it is a subdivision of the User Program.

Node: the point on a PC Ladder Rung where a logic element is entered into a Ladder Logic Diagram.

Noise: random unwanted electrical signals, usually generated outside the Controller, which can cause errors in a PC managed system.

Non-Volatile Memory: memory which does not lose its information when power is turned off.

Normally Open Contact (Examine On Contact): a Contact whose not active state is Open. It is examining for an ON Signal in order to go active and close.

Normally Closed Contact (Examine Off Contact): a Contact whose not active state is Closed. It is examining for an OFF Signal in order to pass power. If it finds a voltage ON signal at an input location, it goes Active, opens, and will not pass power.

O

Octal: the Base Eight Numbering System which is used by some PC Manufacturers for Addressing I/O terminals and Referencing Registers.

Off-Line Operation: equipment or devices which are operating, but not affecting the system.

On-Line Operation: operations where the PC is directly controlling a machine or process.

One-Shot: a discrete reference, usually a Logic Coil, which is energized for exactly one scan of the Controller's Logic.

Optical Coupler: a device which uses a light source and a detector to link two points and provide electrical isolation. Often found in I/O Modules.

OR Circuit: a Parallel Circuit which allows one or more alternate paths for power flow in the Logic.

Output Signal: a signal coming from the Controller to the Field Devices in an operation. It can be discrete, turning Field Devices OFF and ON. Or it can be Numeric, displaying values stored in Registers. Or it can be Analog, sending a proportional signal to a Field Device.

Output Field Devices: devices such as Solenoids, Motor Starts, and Readouts which receive signals from the PC.

Output Module: a device used to connect the PC with working devices in the field. It serves two primary functions: converting PC signals to usable output voltages and isolating the PC from power fluctuations in the Field.

P

Parity Check: an error test which counts the number of "1s" in a binary Digit and records whether it is odd or even.

Parallel Circuit: (see OR Circuit)

Peripheral Equipment: units which may communicate with a PC but are not part of it.

Port: an I/O connection point on a Controller or Peripheral Device.

Processor: the "brain" of the PC which performs all the decision-making in the Controller.

Programmable Controller (PC): a solid-state Control System which contains a User Programmable Memory for the storage of instructions to perform specific functions in an Operation. A PC consists of a Central Processing Unit and an I/O Interface. It requires a Programming Device to enter a User Program into its Memory.

Programming Device: a device designed to allow inserting, monitoring, and editing a User Program in the PC.

PROM (Programmable Read-Only Memory): a retentive Memory used to store data.

Teacher Supplement 1

R

RAM (Random Access Memory): a portion of the Memory which is used to store the Information necessary to control a particular operation. This information can be accessed at Random by the processor when it is needed.

Reference Numbers: numbers which identify Elements of the Relay Ladder Logic. These Elements can be either Discrete or Numeric.

Register: a piece of the Controller's Memory which has been set aside for the storage of Numeric Values. The contents of these Registers can be referenced and used by the PC during its operation.

Register Module: sometimes called Numeric and Analog Modules, these I/O Modules allow numerical data to pass between the PC and the Field Devices.

Relay: an electromechanical device which controls other devices in an electrical system.

Relay Element: a Logic Symbol used to simulate the effect of an electromechanical Relay in a User Program.

Retentive Elements: on certain Controllers, these Logic Elements will retain their state or value under specified conditions, e.g., a Retentive Latched Coil may remain latched when power is removed from the PC; a Retentive Timer will retain its Accumulated Time during a power outage provided battery power is supplied.

ROM (Read Only Memory): a portion of Memory which is usually programmed by the Manufacturer and contains basic instructions for the PC.

Rung: a single horizontal line in the Ladder Logic which may contain User Program Elements.

S

Scan: the cycle a PC performs several times each second, during which it reads the inputs, solves the User Program, and sets the outputs.

Scratch Pad Memory: a temporary portion of Memory where the PC stores the data it needs to perform calculations or control an operation. Often this area is used because it offers faster access time than the Main Memory.

Sequencer: a Logic Element which allows events to be programmed to follow a certain order under specified conditions.

Series Circuit: (see AND Circuit)

Skip Function: on certain Controllers, this function allows certain portions of a Program to be skipped when the Logic is being scanned.

Software: application and internal programs which are used to support the performance of the Controller.

Solid-State: circuitry using only integrated circuits, transistors, diodes, etc., and containing no electromechanical devices or vacuum tubes.

Teacher Supplement 1

Status Light: an LED Indicator found on most I/O Modules which can be used as a maintenance aid. It usually lights to indicate that an Output Module is receiving valid data from the Processor, or that an Input Module is receiving a signal from a Field Device.

T

Table: a group of consecutive Memory Registers used to store numerical values.

Timer: a Logic Element which uses the PC's internal clock to time an event or sequence of events. (see Retentive if your Controller allows this function.)

Traffic Cop: a portion of Executive Memory which controls how input and output data are handled.

Transitional Contact: a Contact which will pass power for exactly one scan whenever the Coil or Discrete Input to which it is referenced goes from OFF to ON or ON to OFF (depending upon the transitional type selected).

Triac: a semi-conductor device which acts as an electronic switch for AC loads.

Truth Table: a listing which shows the state of an Output under all the possible Input conditions.

U

Up-Load: transferring data to the PC from a device such as a Programmer.

User Memory: the area in memory where the Application, or User Program is stored.

User Program (Application Program): a set of Instructions written by the user and stored in the Memory. These instructions "tell" the Processor how to control a specific operation.

V

Volatile Memory: a type of Memory which will lose its information if power is removed from it.

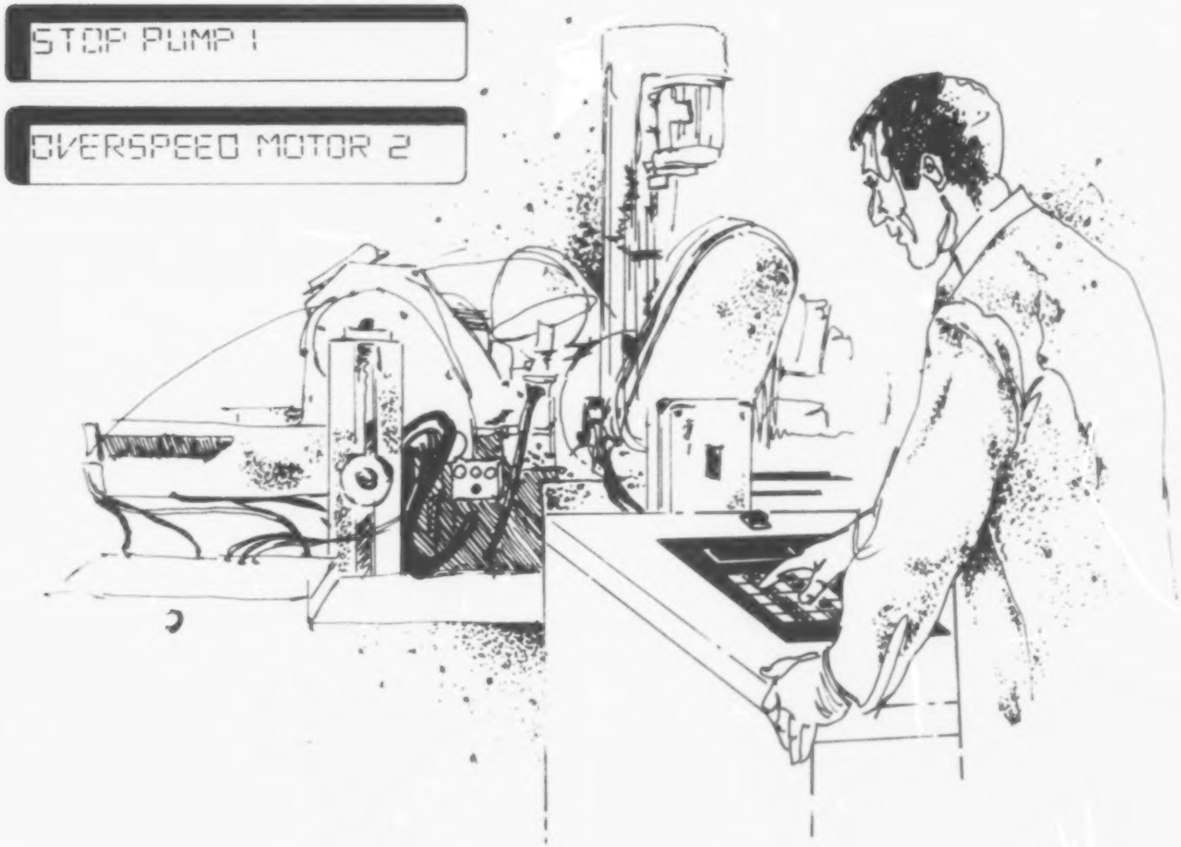
W

Watchdog Timer: a safety circuit which uses a Timer to check constantly for CPU failure. When the CPU is operating correctly, the Timer is periodically reset so it never Times Out. In the event of failure, the Timer Times Out and the entire system is shut down.

Word: a grouping of bits (usually 16) into a sequence which is treated as a unit.

Write: the act of putting data into a storage location.

Application of Programmable Controllers


STOP PUMP 1
OVERSPEED MOTOR 2

Courtesy of Telemechanique

Programmable Controllers
Unit 15

Information Sheet

1. **Terms and definitions**

   a. **Analog signal** — A signal that varies proportionally with some aspect of the environment

      Example: The signal from a pressure transducer that varies with the amount of pressure being applied

   b. **Counter** — A logic element in a PC user program that is used to simulate the operation of electromechanical counters

   c. **Discrete** — A two-state reference in the user program that can be either on or off

   d. **Fiber optics** – Transfer of discrete signals through glass fibers with light

   e. **Input** — A signal that provides the controller information about the system; can be discrete, numeric, or analog

   f. **Logic** — A system that contains digital switching functions, circuits, or devices

   g. **Networking** — Tying in of multiple PCs to communicate with each other in the performance of a process

   h. **Output** — A signal coming from the controller to field devices; can be discrete, numeric, or analog

   i. **Programmer** — A device designed to allow inserting, monitoring, and editing a user program in the PC

   j. **Programmable controller (PC; PLC)** — A solid state control system that contains a user programmable memory for the storage of instructions to perform specific functions in an operation

2. **Programmable controller functions**

   a. The replacement of electromechanical relays, counters, timers, and analog devices with reliable solid-state circuitry

   b. The facilitation of the change of a process at minimum expense and down time

   c. The performance of arithmetic operations that might be required for controlling certain operations

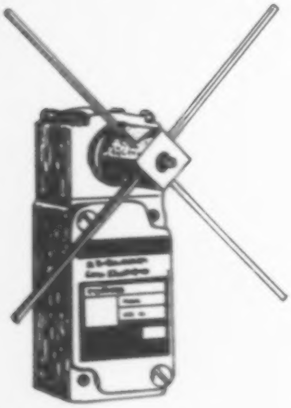
Information Sheet

   d. Fault locating, alarming, and regulation of devices that rarely need attention
   e. The control of dangerous devices or devices in a dangerous environment

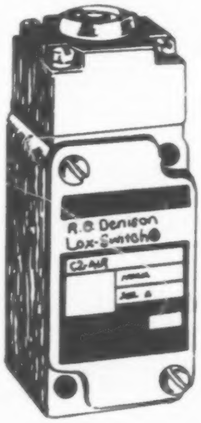
3. **Three stages necessary to control a process**
   a. Input
   b. Logic
   c. Output

4. **Input devices**
   a. Limit switches

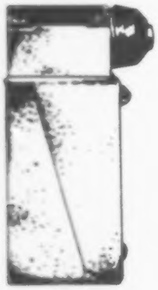
- Turnstile



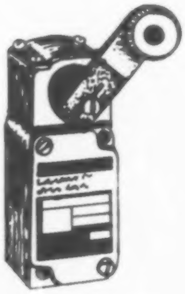
- Air operated



- Two-step sequence

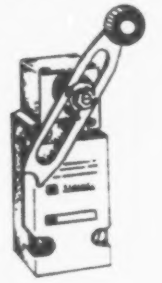


- Turret head



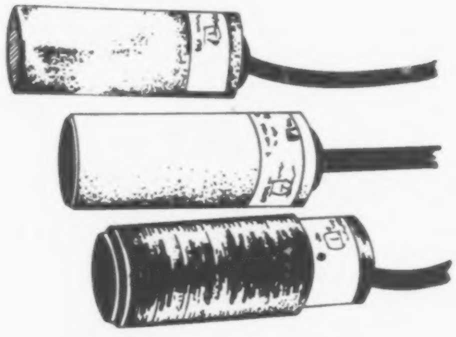
Information Sheet

- Precision turret

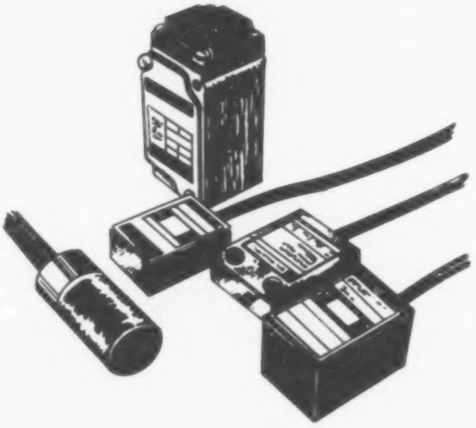


b. Proximity switches

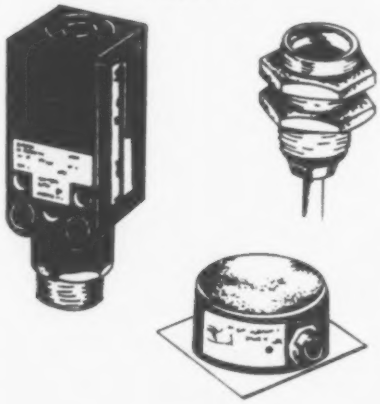
- Capacitive



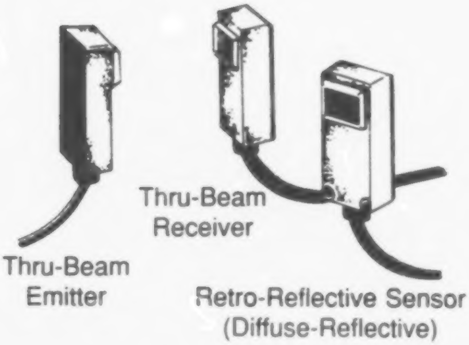
- Magnetic



- Inductive



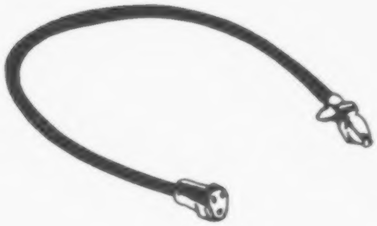
- Photoelectric


Thru-Beam Receiver
Thru-Beam Emitter
Retro-Reflective Sensor (Diffuse-Reflective)

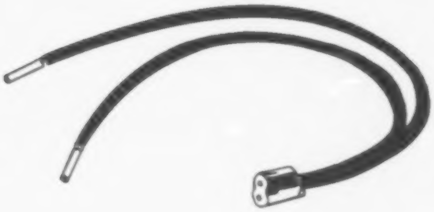
Information Sheet

c. Fiber optic probes

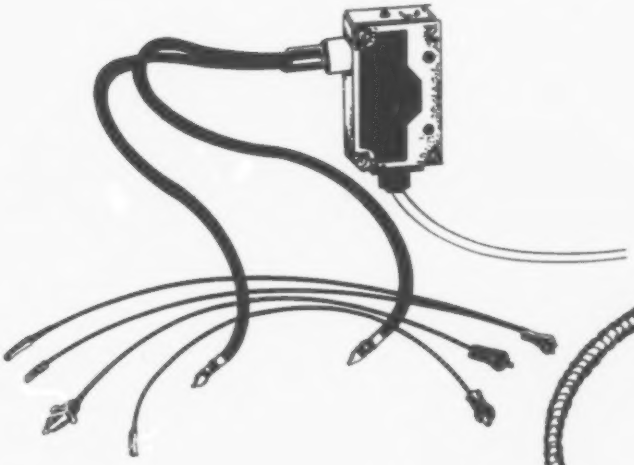
- Coaxial reflective



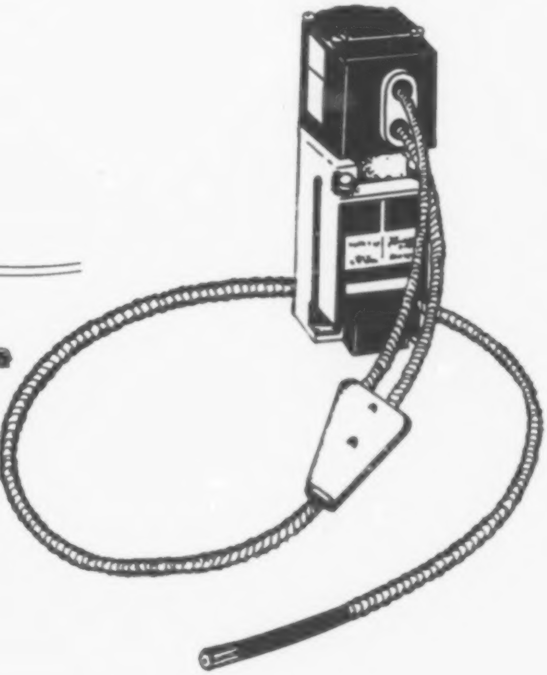
- Thru-beam



- Thru-beam and reflective scanners

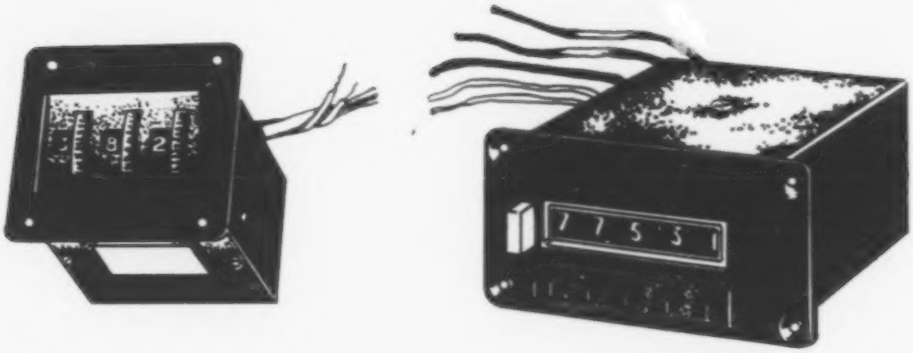


- Scanner cable

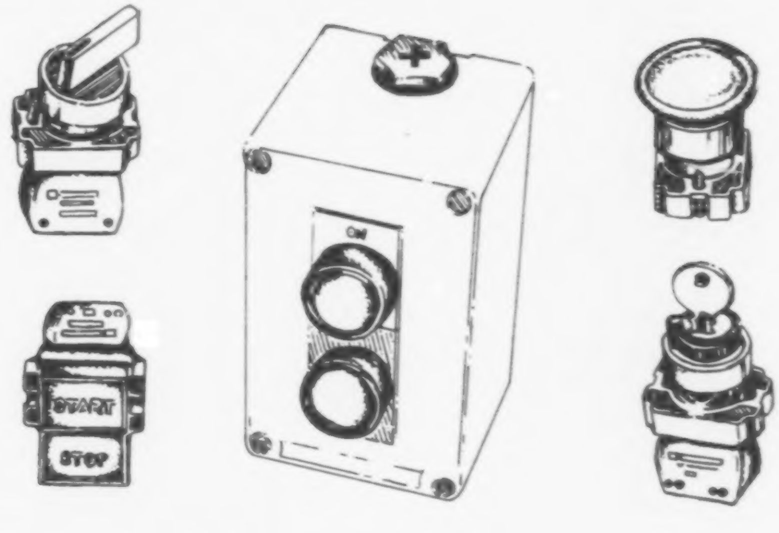


Information Sheet

d. Thumbwheels



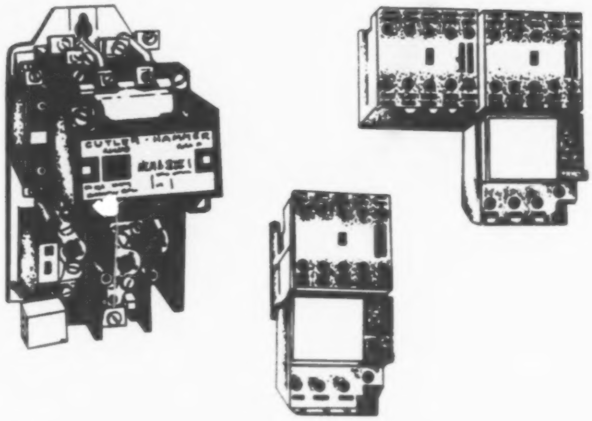
e. Push buttons


ON
START
STOP

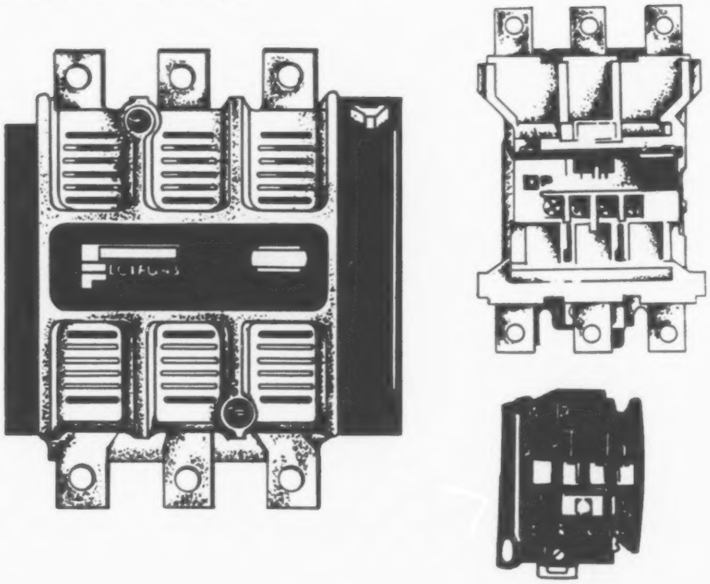
Information Sheet

5. Output devices

a. Motor starters

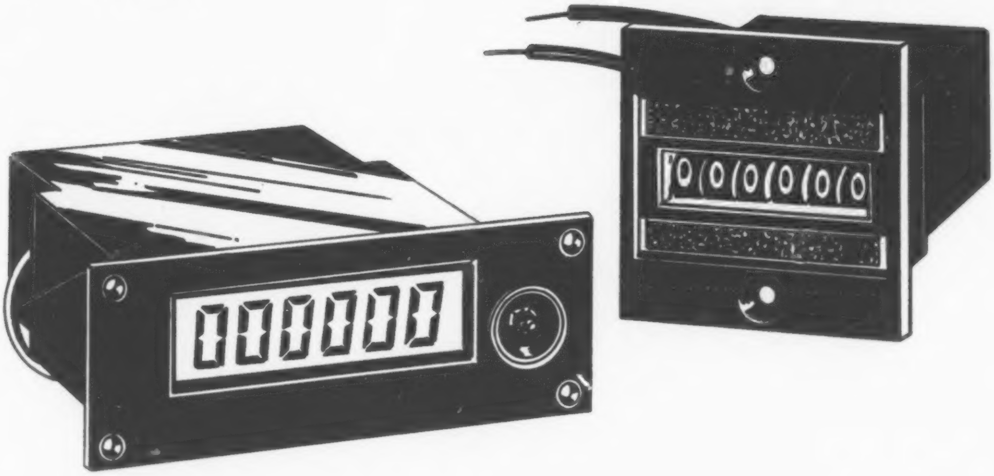

CUTLER-HAMMER

b. Contactors and relays

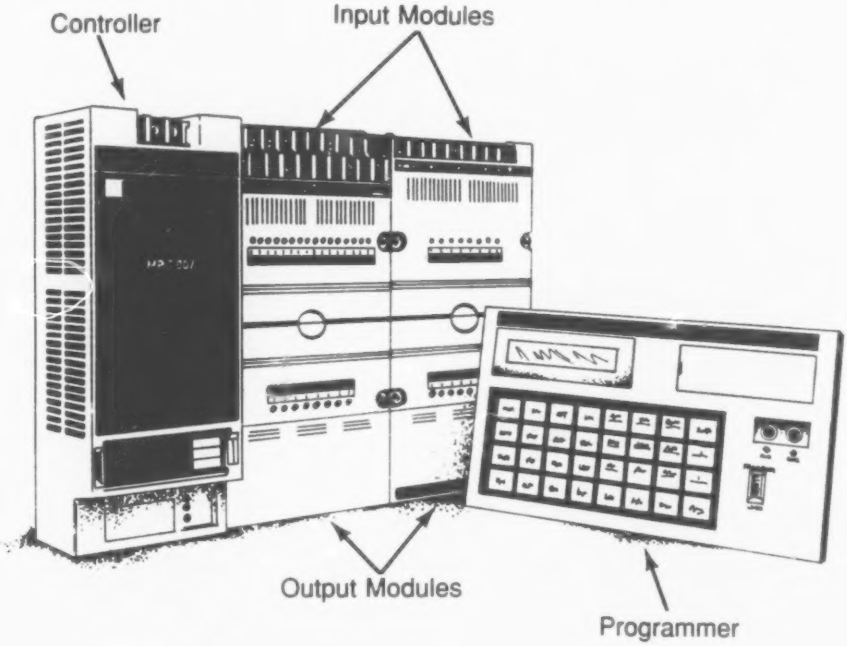


Information Sheet

c. Counters



6. Components of a programmable controller



Controller
Input Modules
Output Modules
Programmer

Courtesy of Telemechanique

Information Sheet

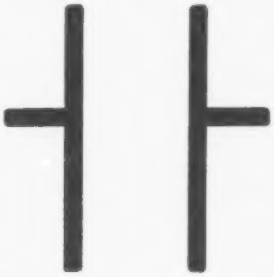
7. **States of contacts**

   a. A normally closed contact will be closed and passing power when it is inactive.

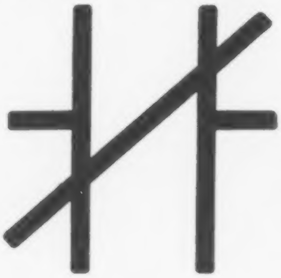
   b. A normally open contact will be open and not passing power when it is inactive.

   c. When activated, contacts change to the opposite state from their normal (non-active) state. In other words, a normally open contact will close and a normally closed contact will open.

Normally Open Contact



Normally Closed Contact



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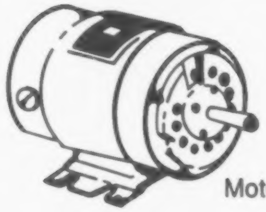
Note: It is important to remember that all relays have contacts associated with them that become active when the coil energizes. Switches also contain contacts that will go active when the switch is activated. All contacts have a normal state, either open or closed, that is the position they are in when they are inactive.

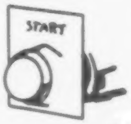
8. **Types of input/output (I/O) modules**

   a. Discrete I/O modules

   Note: These are used for simple two-state, on/off field devices.



Motor

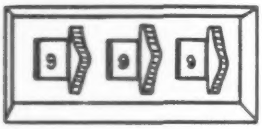


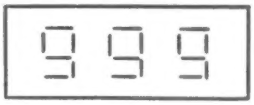
Push Button

Information Sheet

b. Numerical I/O modules

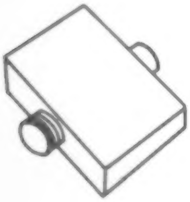
Note: These are used for field devices such as thumbwheels and LED readouts, which send an receive numbers.

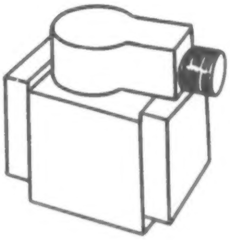

Thumbwheel


LED Display

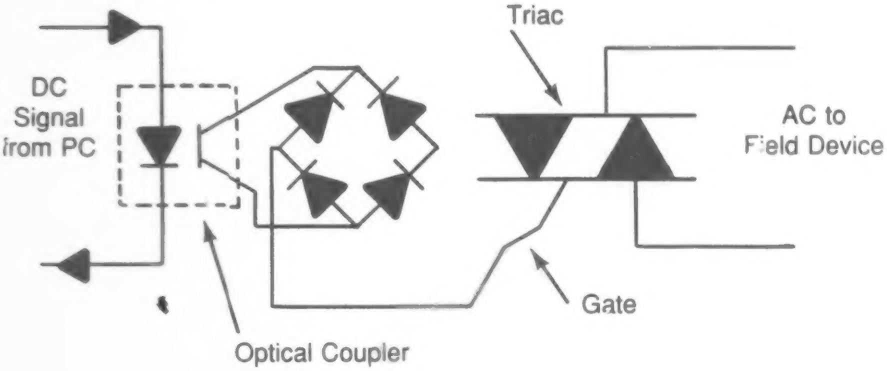
c. Analog I/O modules

Note: These are used for field devices which must send or receive voltage signals that change continuously.


Pressure Transducer


Proportional Analog Valve

9. **Parts of an optical coupler**


DC
Signal
from PC
Triac
AC to
Field Device
Gate
Optical Coupler

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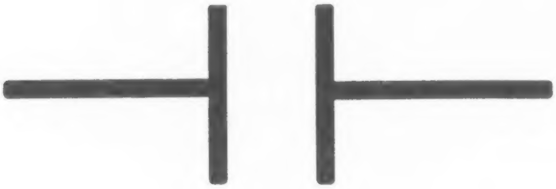
Information Sheet

Note: Two basically independent circuits meet at a triac, which is an electronic switch. When the low voltage DC signal from the PC is applied to the gate of the triac, a switch in the triac will close, allowing AC to flow in the output device's circuit. This system is used to optically isolate the PC circuitry from the field circuitry, thus protecting the PC from transients, spikes, etc.

10. Basic ladder logic symbols

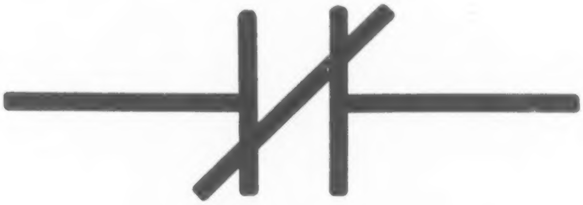
Note: Signals from the input devices in the field are changed by the I/O modules into data which the PC can use. When this data is a simple on/off signal, it enters the logic through contacts on ladder rungs in the user program.

a. Normally open contact (examine on)



Note: Normally open contacts are contacts that remain open and do not pass power when they are not receiving a signal from the input module. They are sometimes called examine on contacts because they are looking for an on signal to pass power.

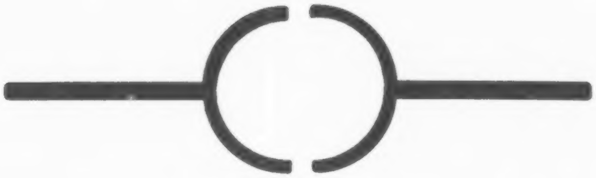
b. Normally closed contacts (examine off)



Note: Normally closed contacts are contacts that remain closed and do pass power when they are not receiving a signal from the input module. They are sometimes called examine off contacts because they are looking for an off signal to pass power.

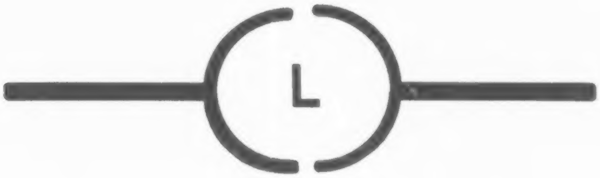
Information Sheet

c. Normal output coils



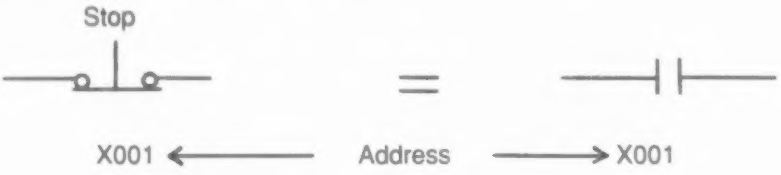
Note: Normal coils have two states. They can be energized and sending a signal to the output module or not energized and not sending a signal.

d. Latched output coils



Note: These are often referred to as retentive coils. On most controllers, a latched coil will remain in its latched state, even when the rung changes state. When this is the case, an unlatching coil is often required to change the state of the output. Consult the PC's User Manual for the details on latching coils in your controller.

11. **Normally closed stop buttons** — Input devices such as stop switches and high limit switches are wired normally closed in the field. However, in the logic, the normally closed contact is programmed normally open. The N/C input device is passing power to the I/O module. Sensing this voltage, the I/O sends an **on** signal to the controller. Since this signal means the device has not been activated, power will flow along the rung as long as the signal is received.



Infromation Sheet

12. Basic numbering systems

Note: Most programmable controllers can perform at least some arithmetic. They do this by comparing the values in one register to one or more different registers.

a. Decimal (Base 10)

b. Binary (Base 2)

c. Octal (Base 8)

d. Hexidecimal (Base 16)

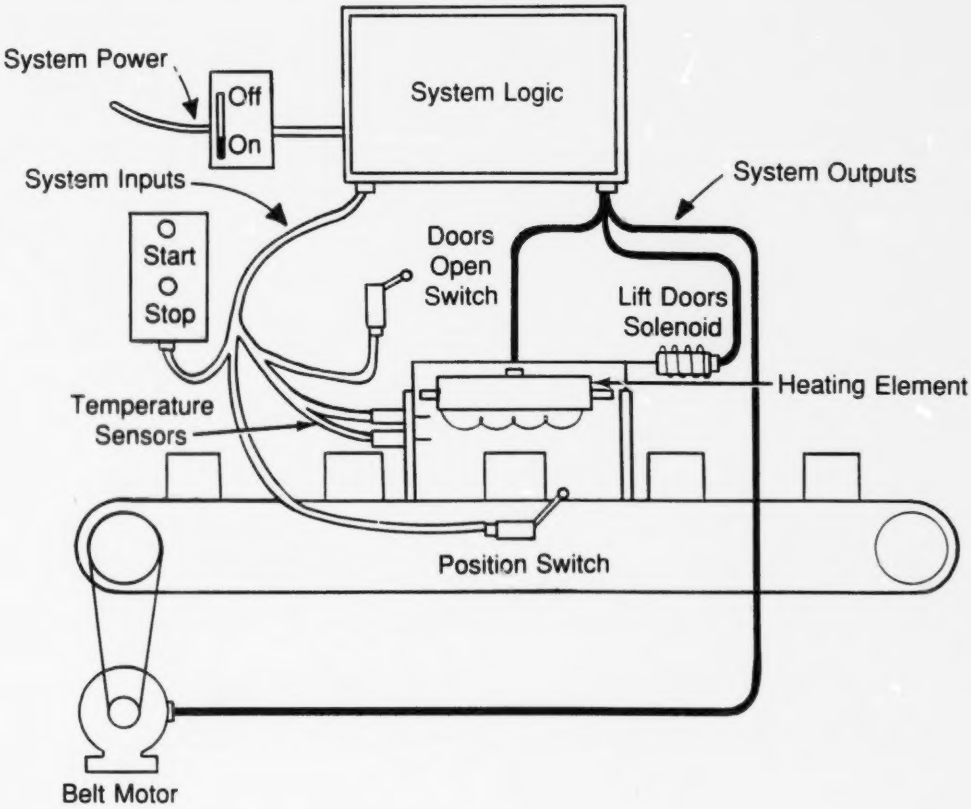
Programmable Controllers
Unit 15

Assignment Sheet 1—Match I/O Devices with Their Functions

Name ______________________________ Overall Rating __________

Evaluation Criteria	**Rating**
Demonstrated understanding of I/O device functions	______
Correct answers given	______

Directions: Using the pictorial drawing of a PC managed system, match I/O devices with their correct functions. The above criteria will be used to evaluate your performance.


System Power
Off
On
System Logic
System Inputs
System Outputs
Start
Stop
Doors Open Switch
Lift Doors Solenoid
Heating Element
Temperature Sensors
Position Switch
Belt Motor

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Assignment Sheet 1

______a. It deactivates, signaling the logic to begin the heating cycle

______b. It signals the logic to begin the process and start the belt moving

______c. Allows the heat to only reach a certain level

______d. Signals the logic that a workpiece is in the oven and to close the doors

1. Doors open switch
2. Position switch
3. Start button
4. Temperature sensor

Programmable Controllers
Unit 15

Assignment Sheet 2—Convert Between Numbering Systems

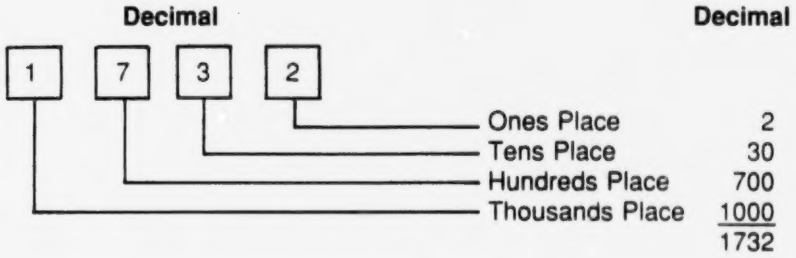
Name ______________________________ Overall Rating __________

Evaluation Criteria	Rating
Demonstrated ability to convert systems	______
Correct conversions given	______

Directions: Study the following descriptions of the various numbering systems, then complete the indicated conversions. The above criteria will be used to evaluate your performance.

Decimal System

The numbering system you are familiar with is called the decimal system. It uses ten unique characters. Each character represents a power of ten.

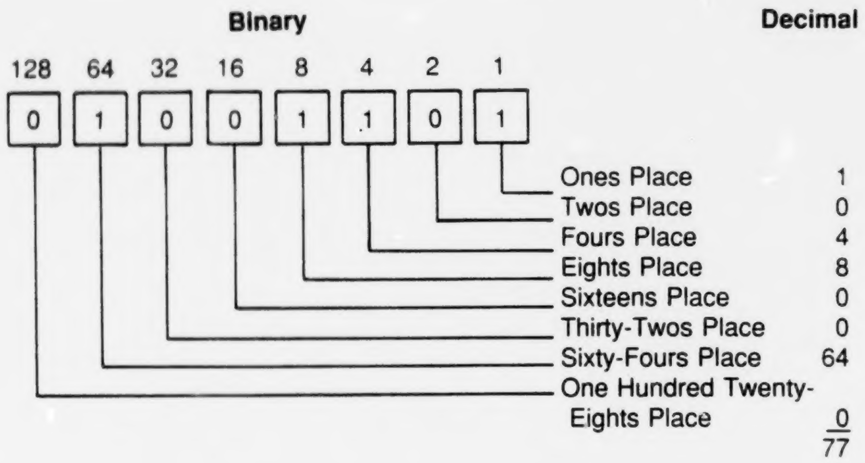

Decimal
1
7
3
2
Decimal
Ones Place 2
Tens Place 30
Hundreds Place 700
Thousands Place 1000
1732

Assignment Sheet 2

Binary System

The on/off status of a switch is easily read by a computer. The binary system is the basis of computer operations. The binary system uses two unique characters (1 and 0). Each character represents a power of two.

When translating a binary number to a decimal number, include the columns which contain a binary one, and disregard the columns which contain a binary zero.

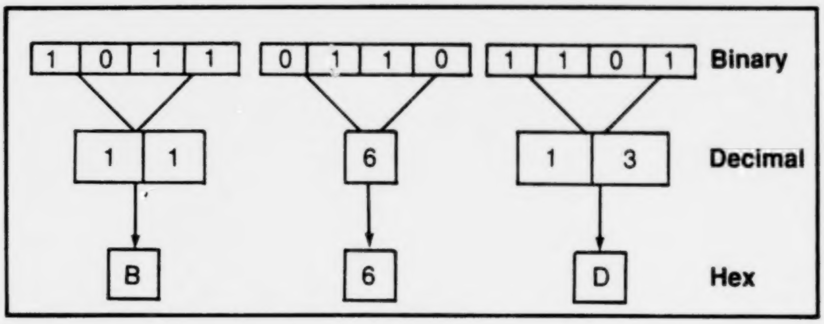

Binary
Decimal
128
64
32
16
8
4
2
1
0
1
0
0
1
1
0
1
Ones Place 1
Twos Place 0
Fours Place 4
Eights Place 8
Sixteens Place 0
Thirty-Twos Place 0
Sixty-Fours Place 64
One Hundred Twenty-Eights Place 0
77

Assignment Sheet 2

Hexidecimal System

Note: Since a computer operates in binary, a coding system was developed to allow the decimal numbers on thumbwheels and readouts to be used by a PC. It is called "Binary Coded Decimal" or "BCD". In the following example, the BCD number shown may be simplified to the hexidecimal B6D.

Hex allows the PC to display a larger number of binary combinations as a three column readout. The hex system uses sixteen unique characters (0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F). Letters A through F represent the decimal numbers 10 through 15.



Binary	Decimal	Hexidecimal
0000	0	0
0001	1	1
0010	2	2
0011	3	3
0100	4	4
0101	5	5
0110	6	6
0111	7	7
1000	8	8
1001	9	9
1010	10	A
1011	11	B
1100	12	C
1101	13	D
1110	14	E
1111	15	F

Assignment Sheet 2

Convert the following as indicated.

A. Decimal 078 =

___ ___ ___ ___   ___ ___ ___ ___   ___ ___ ___ ___ BCD

B. Decimal 493 =

___ ___ ___ ___   ___ ___ ___ ___   ___ ___ ___ ___ BCD

C. Decimal 206 =

___ ___ ___ ___   ___ ___ ___ ___   ___ ___ ___ ___ BCD

D. Decimal 851 =

___ ___ ___ ___   ___ ___ ___ ___   ___ ___ ___ ___ BCD

E. 0101-0001-0110 BCD =

___ ___ ___ Decimal

F. 0011-1001-0010 BCD =

___ ___ ___ Decimal

G. 0010-1000-0111 BCD =

___ ___ ___ Decimal

H. 1010-1001-1111 BCD =

___ ___ ___ Hex

I. 0111-1101-1100 BCD =

___ ___ ___ Hex

J. 0110-0101-1011 BCD =

___ ___ ___ Hex

Scenarios
Special Supplement

Suggestions to the Instructor

The following scenarios are designed to develop in the student the critical thinking skills necessary to make competent judgments based on available data or information. The problems provided in these scenarios will encompass most of the skills learned in the commercial and industrial wiring curriculum. Application of these problems should also develop skills in work ethics and give the student a basic understanding of the economics of the electrical industry. The student should also show marked improvement in communication skills and trade related mathematics.

1. Two-wire control applications
2. Timed operation applications
3. Reversing applications
4. Oil field applications
5. Reversing alternative applications
6. Limitation of movement applications
7. Back spin protection applications
8. Hazardous mixing applications
9. Sequential starting applications
10. Sequential shutdown applications

In order to implement the above scenarios, the instructor should provide:

1. Electrical labor units manual
2. Electrical supply catalogs
3. Pricing books
4. Overhead and markup multipliers (based on local prices)
5. Varied motor control components

It is also suggested that the instructor review the scenarios and construct work stations for each problem. The work stations should have all starters, motors, and raceways installed. The student should be required to determine appropriate control devices as well as conductor size and overcurrent and overload protection. Many of the problems require a bid or price figure. Assist each student with the basics of pricing, overhead, and markup.

Suggestions to the Instructor

Each scenario problem will require a technical report. A detailed explanation of the sequence of operation of the circuit should be included. It should be referenced to the ladder diagram. Any additional pertinent information should also be included, i.e., why a particular NEMA type of enclosure is necessary.

The problems will increase in difficulty as the student progresses through the supplement. The student should be encouraged to perform any necessary research on his/her own. Your role should change from instructor to technical consultant/evaluator.

No answer sheets have been provided for these scenarios due to the varied methods of problem solving.

Scenarios
Special Supplement

Suggestions to the Student

All of the scenarios presented in this supplement are real situations. You will be required to apply all of the knowledge you have gained to this point. Many of the problems provided in these scenarios will require some research in solving the design aspect of the problem. Use the resource materials which are available as well as your imagination. **You are encouraged to create your own solutions.** Do not depend on anyone for assistance except your instructor. Remember, when you begin working in the field you may be required to solve similar problems.

Problems may include bids or a material list. Remember, the electrical market is highly competitive. You must not "gold plate" a job. Your solution should conform to current *NEC* and industry standards. Safety and the customer should always be of the utmost importance.

Scenarios included in this supplement include:

1. Two-wire control applications
2. Timed operation applications
3. Reversing applications
4. Oil field applications
5. Reversing alternative applications
6. Limitation of movement applications
7. Back spin protection applications
8. Hazardous mixing applications
9. Sequential starting applications
10. Sequential shutdown applications

Each of the scenarios listed above will require a technical report as part of the problem solving process. The report should include a detailed explanation of the operation of the circuit and should be referenced to your ladder diagram. In addition, include any other pertinent information such as why a particular NEMA type of enclosure was chosen.

Suggestions to the Student

All calculations must also be included in the report. These should include voltage drop calculations, branch circuit sizing, and overcurrent protection.

When determining the material list, be sure you include all necessary materials such as:

1. Starter (size and type)
2. Overload heaters
3. Disconnect (size and type)
4. Fuses
5. Conduit
6. Connectors and couplings
7. Liquidtight
8. Flex
9. Junction boxes and covers
10. Screws
11. Straps
12. Any other materials not listed above

Scenarios
Special Supplement

Scenario 1—Two Wire Control

Name ____________________ Score __________

Part 1: Evaluation

It is important that your drawing and written reports are of the highest quality. These items will be returned to you for inclusion in a portfolio upon graduation. All calculations must be included in the report.

Circuit Design	—	30 points
Conformity to Code	—	25 points
Workmanship	—	20 points
Time	—	25 points
Technical Report	—	100 points

Start Time ____________________ Instructor's Initials ______

Completion Time ____________________ Instructor's Initials ______

Possible Points		Points Deducted/Reason	Points Earned/Comments
Design	30		
Code	25		
Workmanship	20		
Time	25		
			Total Pts. Earned
Technical Report	100		Total Report Pts. Earned
			Grand Total

Scenario 1

Part II: Problem

A trucking company with an extremely large loading dock has a problem with standing water after every heavy rain. The area where the trucks back in has been excavated to a depth of 5.5 feet below the street level. Since this is below the level of the city storm sewer, it is impossible to drain the area with gravity. A plumbing company has installed two lift pumps to force the water uphill to drain it to the sewer.

One pump is 160 feet from the panel, the other is 240 feet from the panel. Both motors are ¾ HP 240V 3φ squirrel cage units. It will be necessary to operate the controls by float switches located in sumps.

This job will be done on a cost-plus basis. You will need a complete material list for billing purposes.

Time Limit: ____________

Scenario 1

ELECTRICAL PRICING SHEET

JOB

WORK

ESTIMATE NO

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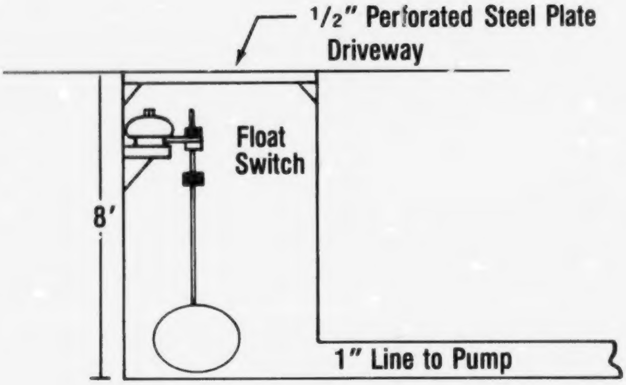
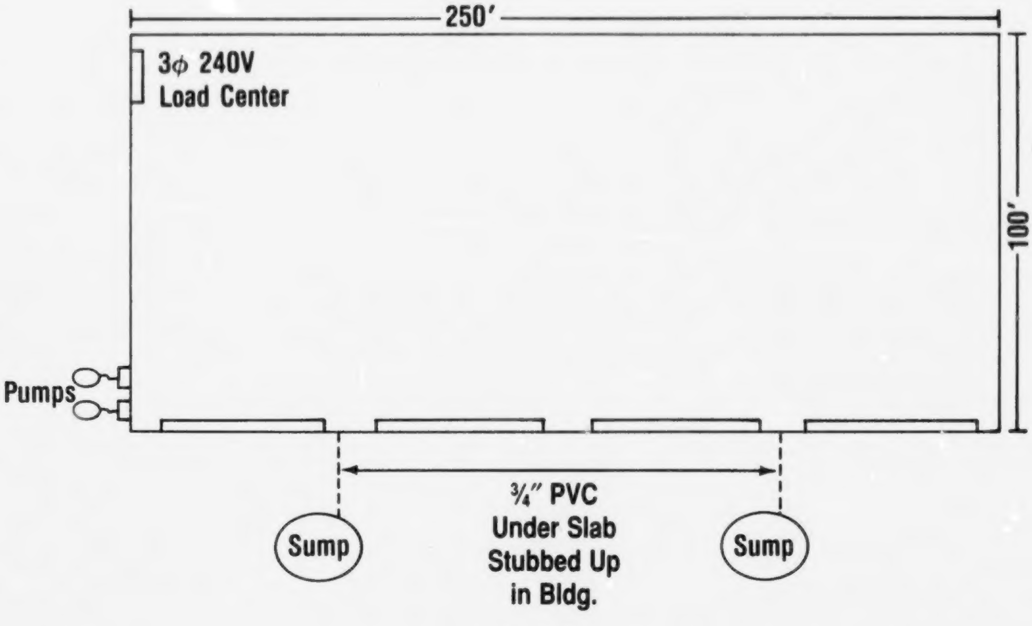
Scenario 1

Detail


1/2" Perforated Steel Plate
Driveway
Float Switch
8'
1" Line to Pump

Floor Plan


250'
3φ 240V Load Center
100'
Pumps
Sump
¾" PVC Under Slab Stubbed Up in Bldg.
Sump
Dock Area

Scenarios
Special Supplement

Scenario 2—Timed Operation

Name ______________________________ Score ______________

Part 1: Evaluation

It is important that your drawing and written reports are of the highest quality. These items will be returned to you for inclusion in a portfolio upon graduation. All calculations must be included in the report.

Circuit Design	—	30 points
Conformity to Code	—	25 points
Workmanship	—	20 points
Time	—	25 points
Technical Report	—	100 points

Start Time ______________________________ Instructor's Initials ______

Completion Time ______________________________ Instructor's Initials ______

Possible Points		Points Deducted/Reason	Points Earned/Comments
Design	30		
Code	25		
Workmanship	20		
Time	25		
			Total Pts. Earned
Technical Report	100		Total Report Pts. Earned
			Grand Total

Scenario 2

Part II: Problem

A chemical company has contracted your firm to install a control system to operate a mixing pump. The pump must run for one hour, then shut down for one hour. This cycle must continue 24 hours a day. There must also be a means of turning the pump on manually, and a way to turn it off for tank cleaning. The mixing pump is a 7.5 HP, 240 volt, 3ϕ unit. It is located 475 feet from the distribution panel. The chemicals held in the tank are non-corrosive, non-explosive mixtures. The tank is located in the main building. The building is a steel structure.

This will be billed as a cost-plus job. You will be required to make a complete material list and price (your cost) each item.

Time Limit: ____________

Scenario 2

ELECTRICAL PRICING SHEET

JOB

WORK

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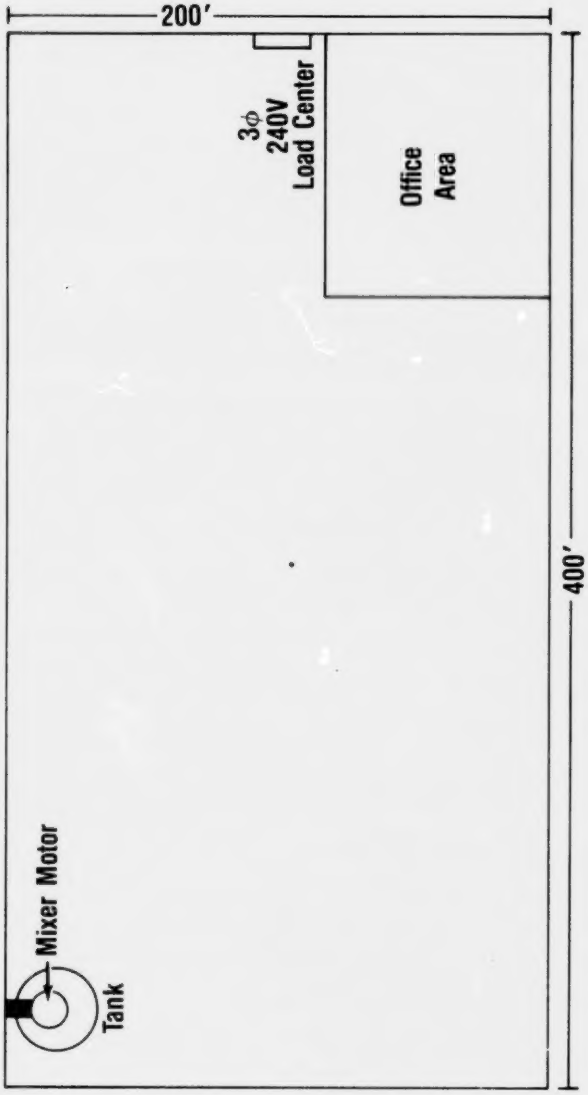
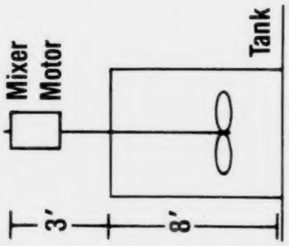
Scenario 2


200′
400′
3ϕ
240V
Load Center
Office
Area
Mixer Motor
Tank

Detail


Mixer
Motor
Tank
3′
8′

Scenarios
Special Supplement

Scenario 3—Reversing Applications

Name ______________________________ Score ______________

Part 1: Evaluation

It is important that your drawing and written reports are of the highest quality. These items will be returned to you for inclusion in a portfolio upon graduation. All calculations must be included in the report.

Circuit Design	—	30 points
Conformity to Code	—	25 points
Workmanship	—	20 points
Time	—	25 points
Technical Report	—	100 points

Start Time ______________________________ Instructor's Initials ______

Completion Time ______________________________ Instructor's Initials ______

Possible Points		Points Deducted/Reason	Points Earned/Comments
Design	30		
Code	25		
Workmanship	20		
Time	25		
			Total Pts. Earned
Technical Report	100		Total Report Pts. Earned
			Grand Total

Scenario 3

Part II: Problem

A call has just come in to the dispatcher of your electrical contracting firm. The customer has requested that you install a control to reverse the rotation of a large fan located in the gable end of his automotive repair shop. It will be used to exhaust fumes, and to bring in fresh air. The customer wants two control stations, one located directly below the fan, the other in the office. The fan motor is a 3ϕ, 3 HP, 208 volt unit. The owner has requested that you prepare a proposed cost figure before doing the job. He has furnished you with a rough drawing of his building for bidding purposes. The building is a wooden structure with no ceilings in the shop area, and the interior walls of the shop are covered with ½″ plywood. The fan is 17 feet above the floor.

Time Limit: ____________

CIW-455

Scenario 3

ELECTRICAL PRICING SHEET

JOB ____________________

WORK ____________________

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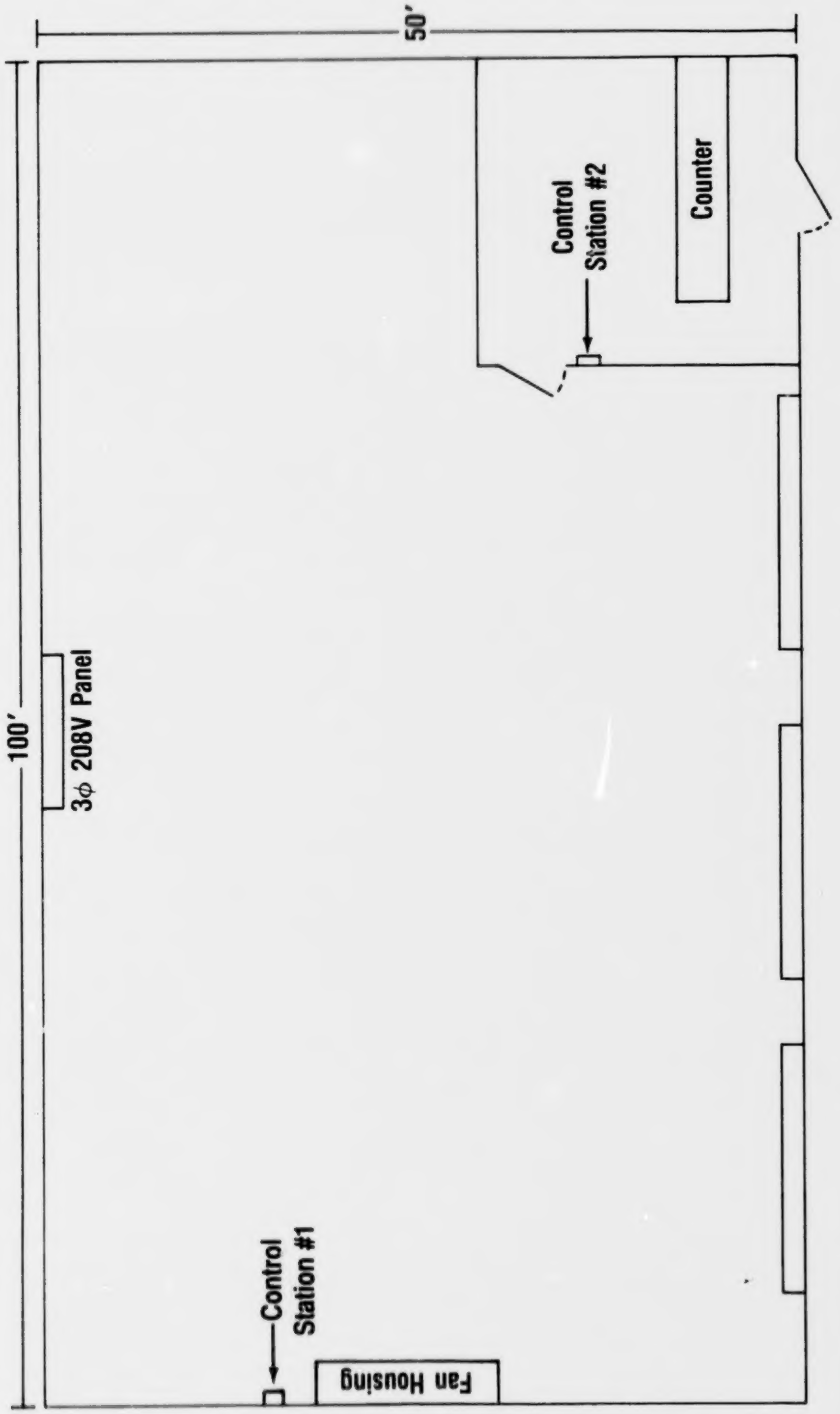
Scenario 3


50′
100′
3ϕ 208V Panel
Control Station #2
Counter
Control Station #1
Fan Housing

CIW-457

Scenarios
Special Supplement

Scenario 4—Oil Field Applications

Name ______________________________ Score ______________

Part 1: Evaluation

It is important that your drawing and written reports are of the highest quality. These items will be returned to you for inclusion in a portfolio upon graduation. All calculations must be included in the report.

Circuit Design — 30 points
Conformity to Code — 25 points
Workmanship — 20 points
Time — 25 points
Technical Report — 100 points

Start Time ______________________________ Instructor's Initials ______

Completion Time ______________________________ Instructor's Initials ______

Possible Points		Points Deducted/Reason	Points Earned/Comments
Design	30		
Code	25		
Workmanship	20		
Time	25		
			Total Pts. Earned
Technical Report	100		Total Report Pts. Earned
			Grand Total

Scenario 4

Part II: Problem

Wildcat Oil Company, a steady customer, has requested that you install a 480 volt, 5 HP, 3ϕ motor on a small pumping unit. This job will include the complete rebuilding and rewiring of a Cutler-Hammer pump panel. Remember, when wiring a pump jack it is necessary to ground your equipment at the wellhead to eliminate any difference of potential. The job will not require a material list, however, your technical report must list the overload and overcurrent protection requirements.

Time Limit: ____________

CIW-459

Scenarios
Special Supplement

Scenario 5—Reversing Alternatives

Name ______________________________ Score ______________

Part 1: Evaluation

It is important that your drawing and written reports are of the highest quality. These items will be returned to you for inclusion in a portfolio upon graduation. All calculations must be included in the report.

Circuit Design — 30 points
Conformity to Code — 25 points
Workmanship — 20 points
Time — 25 points
Technical Report — 100 points

Start Time ______________________________ Instructor's Initials ______

Completion Time ___________________________ Instructor's Initials ______

Possible Points		Points Deducted/Reason	Points Earned/Comments
Design	30		
Code	25		
Workmanship	20		
Time	25		
			Total Pts. Earned
Technical Report	100		Total Report Pts. Earned
			Grand Total

Scenario 5

Part II: Problem

A meat processing plant has an overhead chain conveyor used to transport halves of beef from the cutting room to the cooler. Occasionally it is necessary to run the conveyor in reverse. Since this happens only a few times a month, the owner does not want to go to the expense of installing a reversing starter. A drum switch would be the perfect alternative. The conveyor already has a motor starter and a start/stop station in place. Your job is to install the drum switch to reverse the motor. It will be necessary to check the overcurrent and overload protective devices to be sure that they are of the proper size. This is a cost-plus job, so you must list all materials used as well as hours on the job.

Time Limit: ____________

CIW-461

Scenario 5

ELECTRICAL PRICING SHEET

JOB

WORK

ESTIMATE NO

SHEET NO. OF SHEETS

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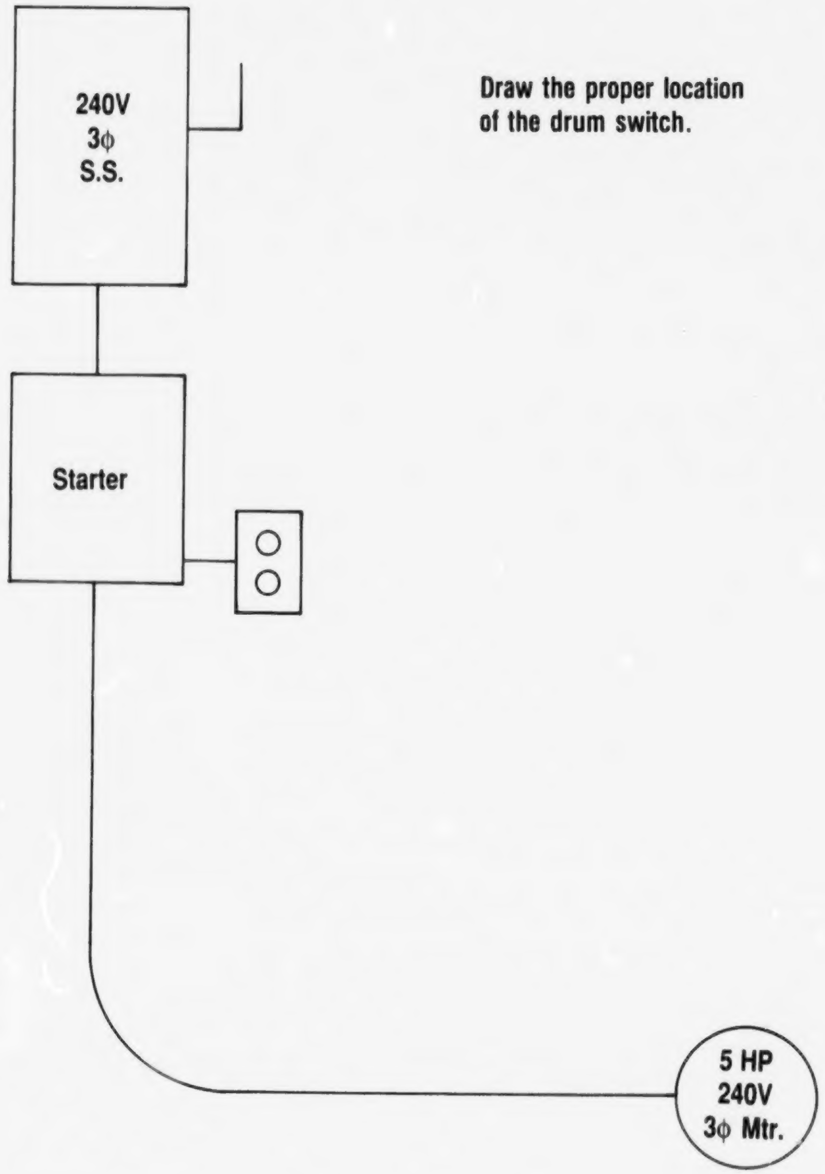
Scenario 5


240V
3ϕ
S.S.
Starter
5 HP
240V
3ϕ Mtr.

Draw the proper location of the drum switch.

Scenarios
Special Supplement

Scenario 6—Limitation of Movement

Name ______________________________ Score ______________

Part 1: Evaluation

It is important that your drawing and written reports are of the highest quality. These items will be returned to you for inclusion in a portfolio upon graduation. All calculations must be included in the report.

Circuit Design	—	30 points
Conformity to Code	—	25 points
Workmanship	—	20 points
Time	—	25 points
Technical Report	—	100 points

Start Time ______________________________ Instructor's Initials ______

Completion Time ______________________________ Instructor's Initials ______

Possible Points		Points Deducted/Reason	Points Earned/Comments
Design	30		
Code	25		
Workmanship	20		
Time	25		
			Total Pts. Earned
Technical Report	100		Total Report Pts. Earned
			Grand Total

Scenario 6

Part II: Problem

A welding shop has just gotten a contract to build pressure vessels. Since these items are so large, it has become necessary to cut a larger door in the side of their metal building. The door is so large that it is impossible to use an overhead door. The new door will run on a track and slide along the wall. Your job is to install the electrical power and control circuits for the new door. You will be competing for the job with several other electrical contractors. You must visit the shop and make a sketch of the building, panel location, and door location. This sketch will be used for bidding purposes.

You must install limit switches to limit the travel of the door when opening or closing. Remember, when the door is open fully and against the limit switch, you must be able to close it or vice versa.

Time Limit: ____________

Scenario 6

ELECTRICAL PRICING SHEET

JOB

WORK

ESTIMATE NO

SHEET NO OF SHEETS

ESTIMATED BY	PRICED BY	EXTENDED BY	CHECKED BY	DATE

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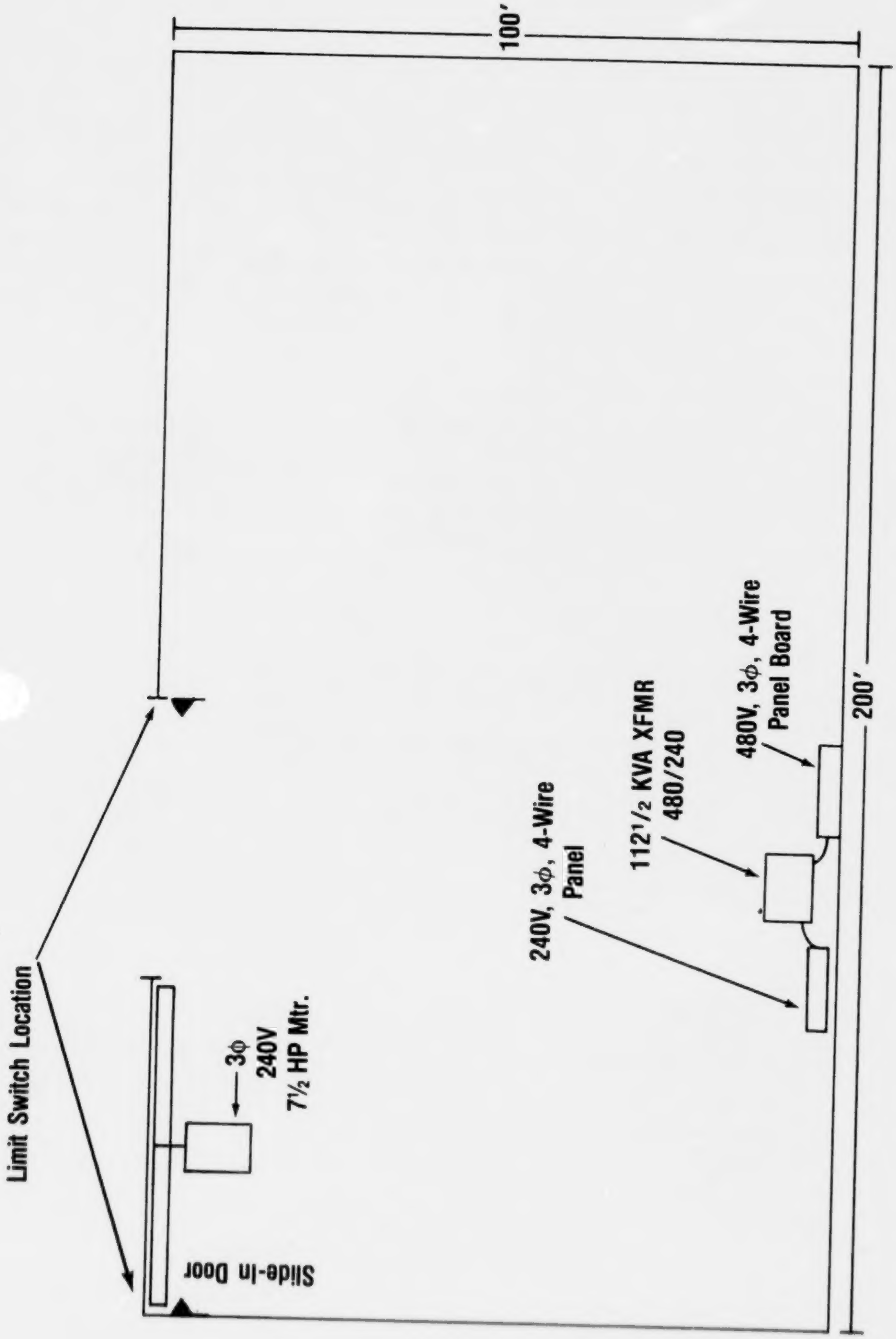
Scenario 6


100'
200'
Limit Switch Location
Slide-In Door
3φ
240V
7½ HP Mtr.
240V, 3φ, 4-Wire
Panel
112½ KVA XFMR
480/240
480V, 3φ, 4-Wire
Panel Board

CIW-467

Scenarios
Special Supplement

Scenario 7—Back Spin Protection

Name ______________________________ Score ______________

Part 1: Evaluation

It is important that your drawing and written reports are of the highest quality. These items will be returned to you for inclusion in a portfolio upon graduation. All calculations must be included in the report.

Circuit Design	—	30 points
Conformity to Code	—	25 points
Workmanship	—	20 points
Time	—	25 points
Technical Report	—	100 points

Start Time ______________________________ Instructor's Initials ______

Completion Time ______________________________ Instructor's Initials ______

Possible Points		Points Deducted/Reason	Points Earned/Comments
Design	30		
Code	25		
Workmanship	20		
Time	25		
			Total Pts. Earned
Technical Report	100		Total Report Pts. Earned
			Grand Total

Scenario 7

Part II: Problem

You have been contacted by the city water department. They have come across a problem that is typical of submerged pumps in deep wells. When the water pressure in the tank is at a point that allows the "down hole" pump to shut down, the water begins to flow back down the hole, forcing the pump's impeller to spin in reverse. If the pressure drops to a point that makes the pump start while this "back spin" is in progress, the pump motor can be severely damaged.

Your job is to correct this problem using your knowledge of motor controls and time delay systems. The pump motor is a 100 HP, 480 volt, 3-phase unit. Upon arrival at the job site, you discover that the motor starter is too small. The director of the water department approves a work order to change the starter while the pump is out of operation.

The conductors feeding the starter and the motor are of the proper size. The existing controls consist of a Murphy switch at the top of the tank to shut the pump down, and a Murphy switch at the bottom of the tank to start the pump. (See attached drawings.)

You will be competing with several contractors for the job, so a bid will be necessary.

Time Limit: ____________

Scenario 7

ELECTRICAL PRICING SHEET

JOB

WORK

ESTIMATE NO

SHEET NO OF SHEETS

ESTIMATED BY	PRICED BY	EXTENDED BY	CHECKED BY	DATE

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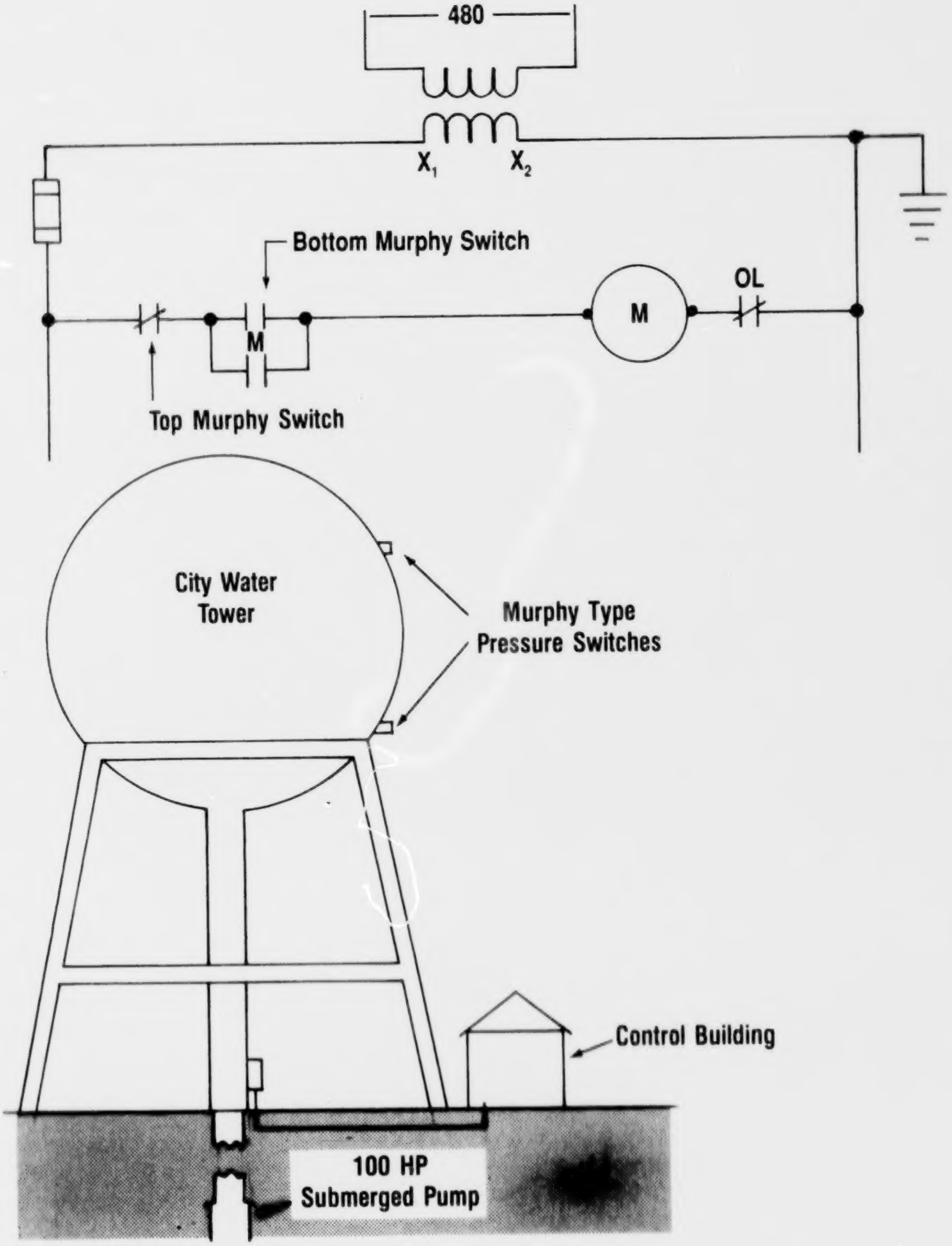
Scenario 7

Existing Controls


480
X1
X2
Bottom Murphy Switch
M
M
OL
Top Murphy Switch
City Water Tower
Murphy Type Pressure Switches
Control Building
100 HP Submerged Pump

Scenarios
Special Supplement

Scenario 8—Hazardous Mixing

Name ______________________________ Score ______________

Part 1: Evaluation

It is important that your drawing and written reports are of the highest quality. These items will be returned to you for inclusion in a portfolio upon graduation. All calculations must be included in the report.

Circuit Design	—	30 points
Conformity to Code	—	25 points
Workmanship	—	20 points
Time	—	25 points
Technical Report	—	100 points

Start Time ______________________________ Instructor's Initials ______

Completion Time ______________________________ Instructor's Initials ______

Possible Points		Points Deducted/Reason	Points Earned/Comments
Design	30		
Code	25		
Workmanship	20		
Time	25		
			Total Pts. Earned
Technical Report	100		Total Report Pts. Earned
			Grand Total

Scenario 8

Part II: Problem

A chemical tank farm has requested you to design and build a delay system for its 3-inch main pump. The pump is used to load trucks (in clockwise rotation), and to unload trucks (in counter-clockwise rotation). In order to avoid any "back-spin" damage to the motor, you have been asked to design and build a system to delay the start of the motor in either direction after the stop button has been depressed.

The existing pump and controls are:

2 forward/reverse/stop stations
1 3-phase reversing Square D starter
You must also add a pilot light to indicate that the system is running.

Include a complete material list of the necessary items to complete the job.

Time Limit: ____________

Scenario 8

ELECTRICAL PRICING SHEET

JOB

WORK

ESTIMATE NO.

SHEET NO. OF SHEETS

ESTIMATED BY	PRICED BY	EXTENDED BY	CHECKED BY	DATE

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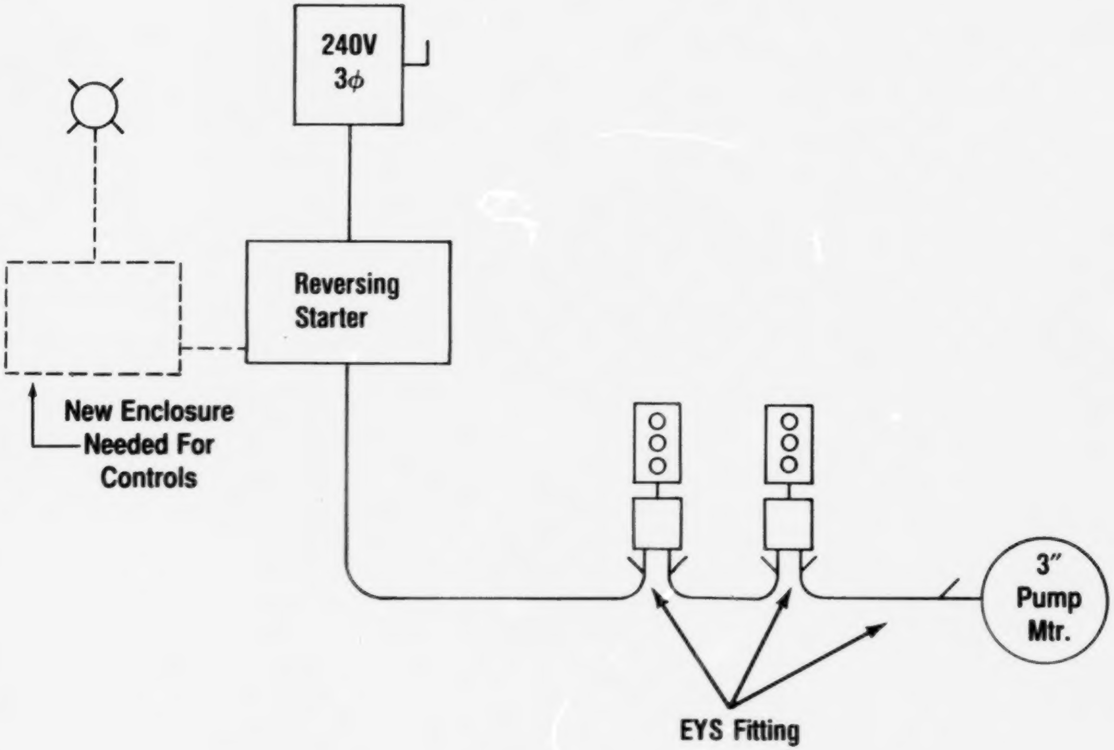
Scenario 8

One Line Diagram


240V
3ϕ
Reversing
Starter
New Enclosure
Needed For
Controls
3"
Pump
Mtr.
EYS Fitting

CIW-475

Scenarios
Special Supplement

Scenario 9—Sequential Starting

Name ______________________________ Score ______________

Part 1: Evaluation

It is important that your drawing and written reports are of the highest quality. These items will be returned to you for inclusion in a portfolio upon graduation. All calculations must be included in the report.

Circuit Design	—	30 points
Conformity to Code	—	25 points
Workmanship	—	20 points
Time	—	25 points
Technical Report	—	100 points

Start Time ______________________________ Instructor's Initials ______

Completion Time ___________________________ Instructor's Initials ______

Possible Points		Points Deducted/Reason	Points Earned/Comments
Design	30		
Code	25		
Workmanship	20		
Time	25		
			Total Pts. Earned
Technical Report	100		Total Report Pts. Earned
			Grand Total

Scenario 9

Part II: Problem

A small aluminum processing company has asked you to install a start-up system in their plant that will allow for an orderly start-up of all equipment in a timed sequential order. As an electrician, you welcome the opportunity for such a challenge. There are seven pieces of equipment that must be included in the start-up.

1. Feed conveyor
2. Shaker #1
3. Grinder
4. Shaker #2
5. Process conveyor #1
6. Process conveyor #2
7. Waste conveyor

Upon actuation of the start button, the feed conveyor will immediately start. A red light will come on to warn all personnel.

One minute later, Shakers #1 and #2 will start.

Forty seconds later, the grinder will start.

One minute later, the process conveyors will start.

Thirty seconds later, the waste conveyor will start.

When the stop button is depressed, all systems will stop. When all systems have ceased to operate, an alarm will sound for fifteen seconds.

Please design a ladder diagram of your control system and submit it with your written report to your instructor for approval before constructing the control system.

Time Limit: ____________

Scenarios
Special Supplement

Scenario 10—Sequential Shutdown

Name ______________________________ Score ______________

Part 1: Evaluation

It is important that your drawing and written reports are of the highest quality. These items will be returned to you for inclusion in a portfolio upon graduation. All calculations must be included in the report.

Circuit Design — 30 points
Conformity to Code — 25 points
Workmanship — 20 points
Time — 25 points
Technical Report — 100 points

Start Time ______________________________ Instructor's Initials ______

Completion Time ___________________________ Instructor's Initials ______

Possible Points		Points Deducted/Reason	Points Earned/Comments
Design	30		
Code	25		
Workmanship	20		
Time	25		
			Total Pts. Earned
Technical Report	100		Total Report Pts. Earned
			Grand Total

Scenario 10

Part II: Problem

In Scenario 9 you designed and built a system for a timed sequential start-up of an aluminum processing plant. In almost all cases, if a timed sequential start-up is required, a timed sequential shut-down is also necessary. Consider the following:

DEPRESS START

1. Waste conveyors start — 30 second delay
2. Process conveyor #2 starts — 30 second delay
3. Process conveyor #1 starts — 30 second delay
4. Shaker #2 starts — 1 minute delay
5. Grinder starts — 1 minute delay
6. Shaker #1 starts — 45 second delay
7. Feed conveyor starts

DEPRESS STOP

1. Red pilot light energizes and feed conveyors stop — 1 minute delay
2. Shakers #1 and #2 shut down — 40 second delay
3. Grinder shuts down — 1 minute delay
4. Process conveyors shut down — 30 second delay
5. Waste conveyors shut down and alarm sounds for 15 seconds

Please complete a ladder diagram of your system with your written explanation and submit these to your instructor for approval before building the system.

Time Limit: ____________